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Status of The Technology for Electrical Road Focusing on Wireless Charging

International Outlook

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Padma Kumar Parameswaran Thampi, Thomas Paul Thodukulam Poulose

HALMSTAD UNIVERSITY

Abstract

The transportation sector has a vital role in today's society and accounts for 20 % of our global total energy consumption. It is also one of the most greenhouse gas emission intensive sectors as almost 95 % of its energy originates from petroleum-based fuels. Due to the possible harmful nature of greenhouse gases, there is a need for a transition to more sustainable transportation alternatives. A possible alternative to the conventional petroleum-based road transportation is, implementation of Electric Road Systems (ERS) in combination with electric vehicles (Evs). There are currently three proven ERS technologies, namely, conductive power transfer through overhead lines, conductive power transfer from rails in the road and inductive power transfer through the road.

The wireless charging or inductive charging electric vehicles (EV) are a type of EVs with a battery which is charged from a charging infrastructure and using the wireless power transfer technology. The wireless charging EVs are classified as stationary or dynamic charging EVs. The stationary charging EVs charge wirelessly when they are parked as well as dynamic charging EVs can charge while they are in motion. Number of studies have reported that, one of the main benefits of dynamic charging is, it allows smaller as well as lighter batteries to be used due to the frequent charging using in the charging infrastructure embedded under roads. The aim of this thesis is to explore the status of developments in the technologies of wireless charging systems for electrification of vehicles and to analyse the developments of ER systems in developed countries to understand the effective method used for fuelling all Electric vehicles in an international outlook.

The findings show that not all countries are viable for ERS from an economic standpoint, however, a large number of countries in the world do have good prospects for ERS implementation. Findings further indicated that small and developed countries are best suited for ERS implementation. From a technological and Business perspective, the wireless charging system in road was found to be the most attractive ERS technology followed by overhead conductive road ERS technologies.

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1. Padma Kumar Parameswaran Thampi
2. Thomas Paul Thodukulam Poulose

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Abbreviations

Term	Definition
AC	Alternating Current
APS	Aesthetic Power Supply
B	Magnetic Field
BM	Business Model
BMS	Battery Management System
CAN	Controller Area Network
CBA	Cost Benefit Analysis
CO2	Carbon Dioxide
CWD	Charge While Driving
DC	Direct current
DEFRA	Department for Environment, Food and Rural Affairs
DWPT	Dynamic Wireless Power Transfer
eBus	Electric Bus
ECU	Electronic Control Unit
EFC	Emissions Forecasting Tool
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
ERS	Electric Road System
EU	European Union
EV	Electric Vehicle
G	Generation
GHG	Greenhouse Gas
GVW	Gross Vehicle Weight
HEV	Hybrid Electric Vehicle
HF	High Frequency
HGV	Heavy Goods Vehicles
HPDC	High Power Dynamic Charge
ICE	Internal Combustion Engine

ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Energy Commission
IEEE	Institute of Electrical and Electronics Engineers
IPR	Intellectual Property Rights
IPT	Inductive Power Transfer
IPV	Induction Powered Vehicle
KAIST	Korean Advanced Institute of Science and Technology
kHz	Kilo Hertz
KPH	Kilometres Per Hour
kW	Kilo Watt
LDV	Light Duty Vehicle
LKM	Lane Kilometres
LMIC	Low- and Middle-Income Countries
LV	Light Vehicles
LMO	lithium-manganese
LWH	Length Width Height
Maas	Mobility as a Service
MTRL	Market & Technology Readiness Level
MPH	Miles Per Hour
NCA	nickel, cobalt, aluminium
N2N	Node to Node
NO2	Nitrogen Dioxide
NOx	Nitrogen Oxides
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OLEV	Online Electric Vehicle
ORNL	Oak Ridge National Laboratory
PATH	Partners for Advanced Transportation Technology
PF	Power Factor
PHEV	Plug-In Hybrid Electric Vehicle
R&D	Research and Development
SMFIR	Shaped Magnetic Field in Resonance

T	Teslas
TAG	Transport Analysis Guidance
TRL	Technology Readiness Level
VRS	Vehicle Restraint System
WPT	Wireless Power Transfer
YTD	Years to Deployment

Chapter 1

INTRODUCTION

This thesis is our final assignment for the master management engineering given under the program Industrial Management and Innovation. This thesis examines the prospects of electric road systems, abbreviated as ERS, to be a solution to our dependency on the fossil fuels as well as the future of transformation. ERS are technologies that enable the continues electricity transfer to vehicles in motion. In this report we have identified and do the compared form a technological and environmental stand point from a global perspective.

1.1 Background

The global energy usage has seen a constant increase since the industrial revolution then the trend is likely to continue for a foreseeable future. According to the U.S. Energy Information Administration, the world energy consumption is estimated to increase by 56 % until 2040. It is fact that, the transportation is one of the important parts of today's energy-intensive society as well as it accounts for 20 % of our global total energy usage. Moreover, as almost 95 % of this energy originates from the petroleum-based fuels and this results in a huge emission of greenhouse gases (GHG). In fact, it was assumed that in 2014, the transport sector alone accounted for approximately 14% of the total GHG emissions. This development has compelled governments around the world to start setting goals to mitigate the increasing global pollution.

The concept of the electric vehicle was introduced in the year of 1828 by Anyos Jedlik in the form of a small car that runs with a small electric motor. Later between 1832 and 1839, Robert Anderson a Scottish inventor who developed a large electric motor that can drive a carriage. At the same time, there were two small scale EV cars developed one in Holland as well as others in the United State by Thomas Devenport. With the development of his innovation, he introduced the first EV which runs with battery power but this invention was not successful because these batteries cannot run the vehicles for a long-range, so it cannot carry even a small number of people and it was not rechargeable batteries. In this age, these inventions cannot elaborate as much as enough to concur with the future in this field due to the challenges. So, the internal combustion (IC) engines ruled the domain for a while. However, at the beginning of the 20th century, IC engine vehicles widely led to a demand for petroleum and it cause to increase in the amount of carbon dioxide in the atmosphere. To overcome this issue automobile industries started to innovate more in EV vehicles. As a result, slowly hybrid vehicles introduced to the market. According to the Swedish government statement (prop. 2008/09:162) which published in 2009, declaring a goal that by 2030 the Swedish transportation sector should be free from fossil fuels: “The work in lowering the transportation sector’s climate effects is making progress and Sweden should aim for having a transportation sector that is independent of fossil fuels by 2030”. As a first step of reducing fossil fuels, Government Offices of Sweden (2009) set a goal for 2020 that at least ten percentage of the energy used in the transportation sector should be renewable. The benefits that they see through this are, reduction in emission of greenhouse gases as well as harmful particles, reducing the use of petroleum products in the transportation sector would further reduce the political influences in this sector from different oil nations. The possible alternative to fossil fuels is to use more electricity in the transportation sector. As the usage of electricity for the vehicles would result in a decreased usage of fossil fuels and the decrease in usage of energy overall. According to the the (Denier van der Gon et al., 2013; European commission, Martin et al., 2011; Fridstrøm and Alfsen, 2014)to control the Co2 emission from the vehicles, the transport sector needs to replace fossil fuels with low-carbon options, like powering the vehicle fleet with electricity generated from the renewable sources. However, not only the change to alternative fuels is an important for the road transport sector, but also improving the vehicle efficiency as well as improvements in the road freight operations as well as logistics (Mulholland et al., 2018). The European as well as the global electricity systems to be free of carbon emissions in the long run then electrification of the transportation sector should be an increasingly attractive option with time.

The battery technology of today is not sufficient for trucks since they need more energy than the batteries can store. It can only drive the trucks to a short distance. Today, the hybrid technology in trucks uses a battery that gets charged through a power recovery when the vehicle applies its brakes. The E-Road System enables a continuous electricity supply to the truck when in motion, which avoids the problem with a too small storage possibility of electricity in the battery of truck. Similarly, this technology has been used for a long time for the trams, trolleybuses and trains, as well as historically there are also existed cases of electric truck systems. Then by years the hybrid vehicles started to change into completely electric vehicles. This fruit of the industrial revolution people's incomes as well as the available technologies some were beginning to experiment with newer forms of EV transport with the achievement of opportunities than before with the developing technologies.

However, there were a lot of challenges existed to facilitate the recharging of the vehicle batteries. Later these issues somewhat figure out by implementing weird charging units installed in the different parking areas then innovations led this concept to wireless charging methods too but the challenge with this was, it can only charge the vehicle when it is in a stationary condition. To be more advanced in this field researchers studied the better possibilities of the charging methods. As part of this study, the world’s first electric road is being inaugurated in the central city of Gävle in Sweden. This is the two-kilometre strip on the E16 motorway that sees electrified trucks from Scania driven in open traffic which uses the conductive technology developed by Siemens. Interestingly, the beauty of new technology, which is the result of several years of cooperation between the Swedish Government as well as the private sector. All these inventions are not a complete success yet because it can only use for particular brand vehicles. This concept has to be a golden feather in the global market by modifying it into a standardized way that can facilitate charging for all brands of vehicles.

This research is also focusing on the maturity of technologies to find the better method for the future and trying to bring out the market opportunities for that technology in a business perspective. Generally, the Market & Technology Readiness Level (MTRL) framework aims to provide decision makers with a holistic view of a project's maturity in a simple way with a scoring. This offers decision makers a faster way to assess, measure as well as support technology projects. MTRL can be used as a specific tool to formulate a go to market strategy which used in the later phases of the project and it incorporates marketing as well as exploitation methodologies. MTRL can be also used as a project planning tool. In that case, periodic (re-)assessments combined with goal-setting future MTRL scores for the next phase of a project, the simple nature of the planned trajectory from current to future score provides scope as well as focus on the project priorities for the time ahead. The high up of assessing technology readiness for deployment as well as investment purposes can be costly to both large and small businesses. The recent advances in the automatic interpretation of technology readiness levels (TRLs) of technologies can substantially reduce the risk and associated cost of bringing these new technologies to market. Meeting technology-based policy goals without sufficient lead time may present several technologies, regulatory as well as market-based challenges based on the speed of technological adoption in existing and emerging markets. Installing incremental amounts of technologies like, cleaner fossil, renewable or transformative energy technologies throughout the coming decades may prove to be a more attainable goal than a radical and immediate change.0

The ERS with dynamic on-road conductive power transfer (CPT) or the inductive wireless power transfer (IPT) while driving has attracted much interest over the past few years (e.g. Chen, Taylor, & Kringos, 2015; Olsson, 2013a). This is because of the limitations experienced with the batteries used for EVs, which include limited driving range, high battery cost, and the fact that current battery technology makes EVs too heavy for the long-range vehicle categories. The dynamic transfer of electricity can be done through overhead transmissions lines or from the road (L. Chen et al., 2015; Olsson, 2013a). Electricity transfer systems that use the overhead transmission lines are conductive, with the vehicle connecting to the transmission lines through a type of pantograph, whereas the road-based technologies can be either conductive or inductive. In the case of a conductive system, the supply of electricity is through a physical pick-up that connects to an electrified rail in the road, where in the inductive system, the electricity is supplied through a wireless power transfer from a coil in the road to a pick-up point in the vehicle (L. Chen et al., 2015; Olsson, 2013a). From the previous studies in the scientific literature, they have investigated ER system mainly with respect to technology improvements, like transfer efficiency (Wu et al., 2012), alignment tolerance of the IPT transformer (Villa et al., 2007), as well as a new three-phase bipolar IPT (Covic et al., 2007). This ERS touches the big system that including the government, leading researchers, policymakers, developers, as well as transportation professionals to exchange and share their experiences about all aspects of ERS in an international setting.

The electric road system can be described in four parts:

1. Existing electricity grid infrastructure - current structure for electricity grid, connection point and electricity grid along the road that supply the electric road with energy

2. Electric road – the technology for power transmission to the vehicle including utilisation measurement system

3. Related services – road fee service, information management, access control

4. Areas of responsibility – maintenance, operation, financing and ownership

1.2 Driving forces in the electricity network market

The technological development has an impact on the electricity network market in many ways. Digitization as well as new IT solutions will create opportunities moving forward which includes the conditions for storing as well as analysing metering data that can be used for product development as well as new service for customers, but also management of electricity networks which creates an efficient electricity system that secures supply.

1.3 Electrification of the transport industry

The significance of electric vehicles in terms of environment as well as health means electrification of the transport industry is an urgent and prioritized issue for the future. The electrification facility for the vehicles has so far mainly reached to passenger cars in cities as well as in 2017 there were almost 45,000 electric cars in Sweden. Electric buses are mainly focused to tested in public transportation, while the electrification of road transportation as well as ports is still at an early stage. The electric vehicles present both an opportunity as well as a challenge for the grid that will lead to increased load and a need for more capacity as well as load control in the long term. However, at the same time offer an opportunity for storage that could balance electricity consumption in the future.

1.4 The historical development of electric road

The electrification of road transportation started from long back ago with the electrically powered public transportation vehicles in urban areas, like the trolleybuses. The original prototype of the trolleybus foregoes to the rail-less ‘electromote’ invented by Dr. Ernst Werner von Siemens, which was presented to the public in Halensee, Berlin in 1882 (“Siemens History Site - Transportation,” 2016). Passengers liked its quiet, vibration-free operation, high performance as well as overload capacity, then operators welcomed its long life as well as low maintenance requirements (Brunton, 1992). However, the operational inflexibility restraints, like being tied to fixed routes, made trolleybuses difficult to integrate with motor buses. The demand for proliferation of road improvement and high cost of the energy and overhead lines made it decline from fashion. As solution to improve the operational flexibility was found in the transfer of the physical contact between the vehicle as well as power source from the overhead to the road surface. The contact can be through a “collector” from electric power rails located in the slot of a conduit below the roadway (Berman and St, 1978). This also can be the contact between the vehicle as well as a conductive strip mounted on the road surface, which that the power take-off system (Jay D. Rynbrandt and Calif., 1984) as well as the mechanical pantograph brush (Michael P. Hennessey, 1994). However, electrical safety issues, reliability and costs have so far restrained the application of these technologies. In recent years, new pantograph types are active under investigation to power the heavy vehicles from conductors either overhead or on road surface, such as the Siemens E-Highway concept (“Siemens History Site - Transportation,” 2015) as well as Volvo’s Slide-in ERS (Olsson, 2013a, 2013b).

Secondly the method to power EVs is the use of onboard storage of energy, such as a battery, which can produce electricity for the EV's power supply when needed. The idea to power a vehicle by a battery dates back to the early test performed by Robert Davidson in 1842 (Post 2007). Then he ran a locomotive with a small battery on the Edinburgh & Glasgow Railway, that achieving a maximum speed of 4 miles per hour only. It is noting that our predecessors were just trying to find a suitable automobile propulsion method, low attention was paid to electric propulsion after the advent of the internal combustion engine. It is due to the urgent concern over our sustainable development in recent decades which the public has been encouraged to reconsider this green as well as renewable solution. The Different types of batteries have been developed and driven by the various important applications including EVs. However, the limitations from the battery technologies, such as range anxiety and high initial costs, still severely restrict the application potential of EVs. To develop EV technology further, focus has thus been given to the associated charging infrastructures, to provide quicker charging at stopping points or even to provide external power when the vehicle is in motion. Currently, the conductive method and the contactless method are two main solutions pursued for charging an EV. The findings show that not all countries are viable for ERS from an economic standpoint, however, a large number of countries in the world do have good

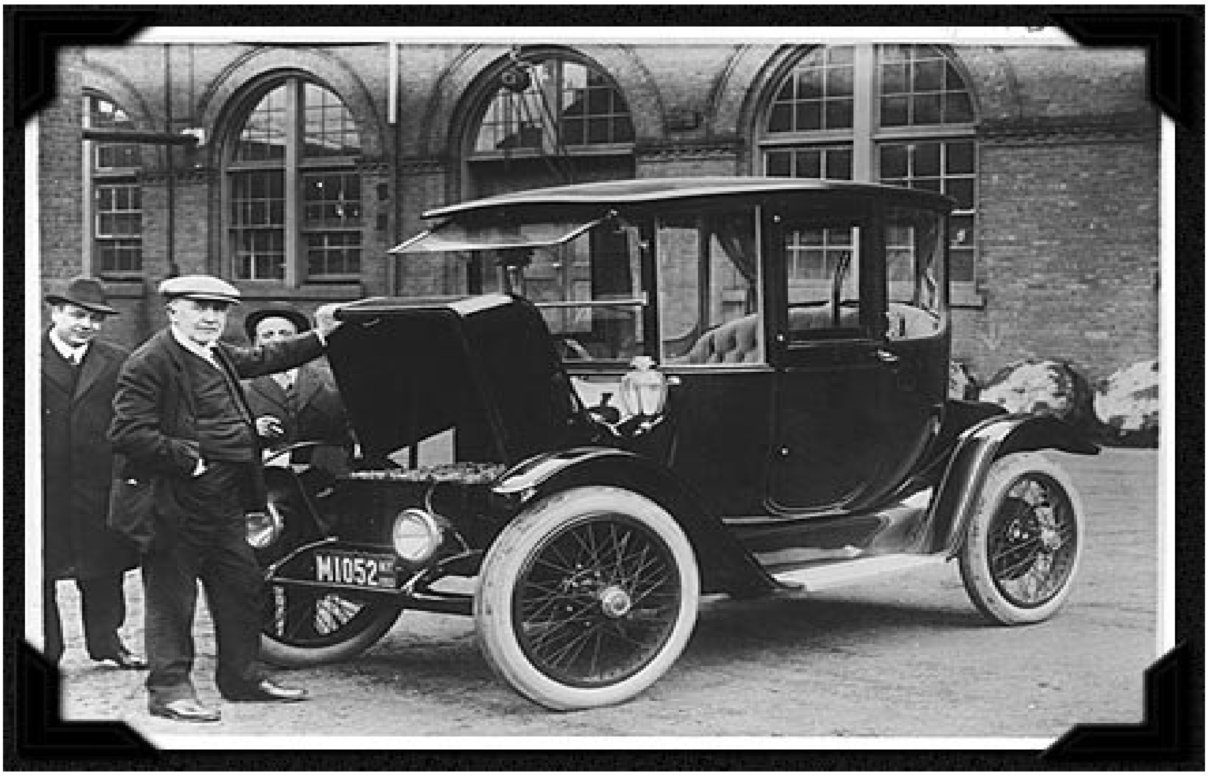


Figure 1.1 First Electric Vehicle model

prospects for ERS implementation. Findings further indicated that small and/or developed countries are best suited for ERS implementation. If it considering from an economic as well as environmental perspective, the conductive road was found to be the most attractive ERS technology followed by the overhead conductive and the inductive road ERS technologies.

Chapter 2

PROBLEMATIZATION

Electric vehicles are using different standards of electric Charging system and batteries as suitable as to different brands. There are different types of charging methods are used in electric cars likewise wired charging and wireless charging. But this is possible while the vehicle is in a stationary condition, also it will take a long time to charge the battery completely. After completely charging the vehicle can travel up to a certain distance in a fully charged condition. To run the vehicle further it needs to charge it again in a stationary condition where the particular vehicle can recharge. It can consume a lot of time and this will disturb the travel and it is difficult to find the charging option for every brand vehicle. However, this technology later advanced to fast charging options, still, this type of charging method cannot be a promising complete solution for the future to overcome the problems related to the IC engine vehicles.

Moreover, companies like Scania introduced electric roads for vehicles like trucks with the help of Siemens technology. This can charge the vehicle by touching the pantograph to the overhead cables. The important drawback is it can only use for the trucks, not to the small vehicles smaller than trucks. To overcome this later Sweden implemented the tracks of rail in the road by a movable arm which attached to the bottom of a vehicle that can use for all vehicles. The drawback with this, there is limitations for several vehicles to charge by this technology at the same time and when the vehicle is stopped then the supply of charge will be disconnected. So, our proposal can help to overcome these challenges and can bring a better face of development in this field.

2.1 Research Purpose

The aim of this thesis is to explore the status of developments in the technologies of wireless charging systems for electrification of vehicles.

A study and analysis to explore the concepts and technologies of electric road systems in developed countries, to understand the effective method used for fuelling all Electric vehicles in an international outlook. This paper is also trying to bring out a possible comparison between TRL and MRL for the better understanding of the electric road system.

Chapter 3

ERS – A New Technological Paradigm

Today, there is a common notion among key actors in the industry that ERS technology is technologically feasible and a way to reduce fossil fuel dependency and emissions in the road system (in spite of huge infrastructure investments required for the technology). There are disagreements among the experts whether the transformation from the diesel engine regime to the ERS will be realized within 10 to 20 or 50 years, but there is a consensus that this transition is possible to come. However, the change is expected to take place gradually, from smaller demonstrations and systems, through closed systems like mining transportation or city bus loops and this to major networks of regional as well as international highways. Hence, there are lot off ERS projects going on around the world at the moment, exploring and evaluating the technology as well as the possibilities of deploying this prospective system on commercial basis and to illustrate more, Pajala (Olsson, 2013b) Los Angeles and Long Beach, California (Green car congress, 2012); Arlanda, Sweden ("Slide-in Electric Road System, Inductive project report," 2018); Bordeaux, France; McAllen, Texas Lommel, Bebblgium (Bombardier, 2012); and Stanford University, California (Green car congress, 2012; Olsson, 2013b).

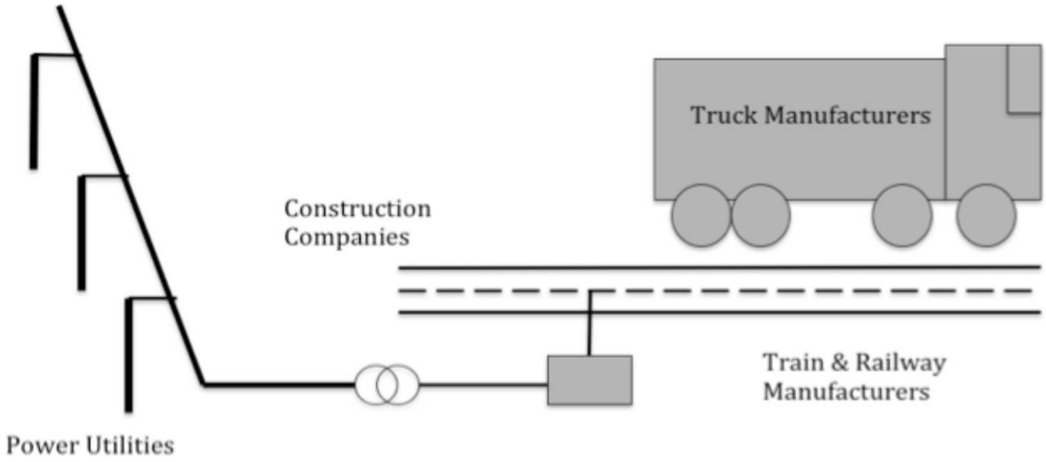


Figure 3.1 Electric road system (Principal design)

Basically, it was actors from railway industry who developed the ERS based technologies. There are various technological solutions available like the power could be transferred to the vehicle by overhead transmissions or through power sources built into the ground (road). The overhead transmission technology is conductive-based and the vehicle connects to the transmission lines through the help of pantograph. The ground-based solution could be either conductive or inductive. If conductive, the vehicle uses a physical pick-up to connect to an electrified rail in the road. Then if it is inductive, there is a wireless power transfer from a coil in the road to a pick-up in the vehicle. Technologically, the overhead line solution is a more mature than the ground-based alternatives (D Bateman et al., 2018).

The ERS technology is already feasible for railroad applications. Deployment on road transportation requires the huge investments in the physical infrastructure, but if it is implemented on full scale, it has significant potential advantages in relation to the existing fossil dependent transportation system and it is fossil independent as well as emission free also it is more energy efficient and reduces operation costs because electricity is cheaper than fossil fuel in many countries; it reduces noise problems allowing vehicle operations at off-traffic hours, which decreases congestion and even out the energy demands. In addition, it has the potential to reduce vehicle maintenance costs since an electric engine is simpler and lighter than a traditional internal combustion engine although this may not be the case in the short term with different powertrains. However, the main barriers for implementation of an ERS are related to increased complexities on the system level. The conventional transportation system has evolved organically over more than 100 years also constitutes today an open socio-technological system with different standards and regulations as well as constituted by different, more or less, autonomous and complementary subsystem. These subsystems such as truck, road, and fuel are today produced and operated autonomously by various actors. To illustrate, truck manufacturers, road authorities, construction companies as well as oil companies. Initially at least, the ERS technology requires a more closed system design, where the subsystems are tightly coupled together. The power train of the ERS-truck needs to be tightly integrated with the power transfer technology, which needs to be integrated with the electric road design, which in its turn needs to be integrated with the regional power grid. Consequently, there are a number of actors from different industries owning strong interests in the different ERS-technologies like manufacturers concerning the vehicle and its power-train; railroad manufacturers concerning the power transfer technology and electric roads technology; construction firms concerning the physical infrastructure and power utilities concerning the electric power supply and operations of the power grid. Moreover, there are many new services required in order to manage ERS such as payment systems, logistics, driver management, electricity metering, and safety, Furthermore, software management services are needed to reduce the complexities of the technological interfaces between ERS and its customers (D Bateman et al., 2018).

Chapter 4

Literature review

Our approach is to identify and implement an inductive charging method while the vehicle is in motion and it helps to save the time for charging to study more in detail about inductive charging methods, initial support is adopted from the articles collected from the library.

Electric Road System (ERS) is the technology which helps to supply electric power to all electric vehicles on the road. The idea to adopt ERS is considered a sustainable practice to offer the potential solution to the road system. It has resulted that now the majority of countries are inclined in the direction of ERS where the implementation of this electric road system is an advanced power transfer to move the vehicles. As per the studies, there are some essential aspects related to the wireless technology of the electric road system. These aspects include vehicle system, transportation system, revenue management, safety and control, energy system as well as power transfer system. These aspects help to ensure the efficient working of ERS where these are strategically essential to regulate the transportation services. The collaborative work of these aspects results in the transfer of power within moving vehicles. The study of (Zupan et al., 2013) discussed five major subsystems associated with the electric road system such as Electric supply, road, power transfer, road operation, and vehicle. Electric vehicle supply equipment (EVSE) technology required a simple, convenient, safe and reasonably fast facility required to charge the vehicle. In the article (Kluth and Ziegner, 2012) explain a study which was to verify the automotive wireless charging method, this study measures the power transfer efficiency with varying levels of the coil to coil air gap and misalignments in roadside and the car coil. The finding of the study areas is the design of the coil system and the necessity for air gap observations. This is clear that the automotive industries going to seek an inductive solution that is smaller, lighter, efficient and less costly these areas along with positioning of technology guidance are the critical area.

In the wireless charging method, the coil structure and the technology are the main areas in a charging system. To overcome this an innovative approach towards the use of superconducting material in designing a coil, after that how this design will potentially impact wireless charging is studied (Machura and Li, 2019). The survey was taken to identify the problems that going to face in wireless EV charging. This survey consists of three parts first one is providing a review of technology-specific to wireless charging EVs, it also reviews some part of modern implementation in wireless charging. The second part of surveys the research on the system issues and operations induce by wireless charging EVs. Third surveys represent the future goal to provide research directions to the researchers and practitioners regarding the trends and guide them for the promising future (Jang, 2018).

Before implementing the ERS infrastructure, there is a need for proper configuration as well as setting of design to implement during the operation. There is the involvement of external factors and internal principles to disclose the system efficiency to analyse the configuration of ERS infrastructure (Gustavsson et al., 2019). Within the configuration, some essential components include the connection of ERS with a medium voltage power grid, infrastructure of power supply and substations. According to (Sundelin et al., 2016), the management of ERS configuration requires to approve the overall procedure of vehicles where (Olsson, 2013a) highlighted the involvement of such factors to modify the design of the vehicles. It includes the influence of various factors towards the system design, as this involves the external factors to discuss. Concerning the ERS, there is an involvement of external requirements to improve the infrastructure by focusing on the approval, social acceptance and procedure to implement. On the other hand, there are specific requirements of the vehicles, including the flexibility of use, vehicle availability, cost pressure, and some technical facilities. As per the study of (M. Taljegard et al., 2017), there are several technical restrictions to show high imposition over the management of ERS infrastructure. This further can say that flexibility and adaptability of the vehicle depends on the model and style of vehicle as each vehicle has a unique requirement and needs. In the article of (Sundelin et al., 2016) highlighted the need for economic optimization to improve the vehicle's operation services. Within the factors of ERS that affect system design, there is a need to highlight some unique design essentials such as the interaction between infrastructure and other vehicle configuration. However, there is consideration to implement all sorts of restrictions, including social acceptance, legal as well as technical ones. The study of (Taljegard et al., 2016) highlighted the assumption of limitations to enhance the technical capabilities of the vehicles. In addition to this, the overall design of the ERS system requires the accurate configuration of the vehicle to deal with the successful implementation of the configuration of the vehicle (Tongur and Sundelin, 2016).

Moreover, recharging of the batteries is considered as one of the essential parameters to increase the effectiveness of batteries. In the article of (Taljegard et al., 2016) the market ramp-up helps to set the power requirement of the infrastructure related to ERS, where there is the inclusion of acceleration and strategies to deal with congestion. This contributes to maintain the increase in the requirement of the power as well as allow the battery to run the vehicle. In the configuration of the ERS development, high value is experienced by the degree of electrification; it includes the economic optimization as well as technical system to enhance the restriction of failure (Wang et al., 2019). For the management of the performance of an electric vehicle, there is a need to maintain the infrastructure components by involving electrification. This acceptance allows lowering the space and reduces the material requirement.

In (Laporte et al., 2019) article they conduct a test by using prototype dynamic inductive power transformation system (IPT) in two serial vehicles, it's an experimental electric road project performed in 2017 with some objectives. The results were obtained from the extensive series of tests in many driving conditions. There are several problems were addressed like global efficiency, current shapes the impact of miss alignment, EMF compliance, measured radiated emission, and charities air gap variation. At last, this research identifies the right dimensioning as well as coverage rate of IPT systems for the long-term applications.

4.1 Theoretical approach

The automobile industries are doing a great revolution through EV concept, to develop a new kind of vehicle for making a great approach in the world. To support this revolution, it is essential that to expand the electric roads then only the EV vehicles can travel a long-range. There are several types of electric charging methods which are Rapid chargers, fast chargers, slow chargers, and wireless chargers, these are used while the vehicle is in statutory condition.

Mainly, there are Five focus areas which currently technology for continuous, vehicle-related power transmission from the infrastructure to the electric road vehicles,

- Conductive transmission through overhead lines
- Conductive transmission through rails
- Conductive in the road inductive transmission through electromagnetic field from the roadbed
- Conductive in road bound capacitive
- Conductive in road side conductive

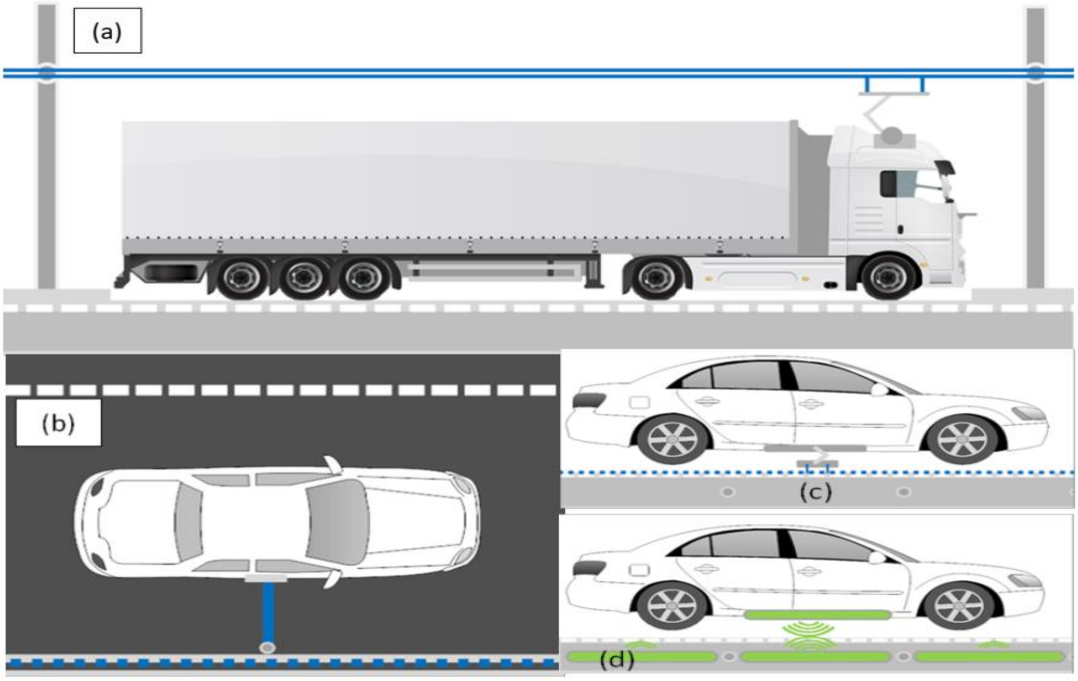


Figure4.1 Types of electric transition system in ERS

First three types have been tested in some part of the world. The technology involving overhead lines has made the most progress. Overhead lines are not suitable for cars as the distance between the roof of the vehicle as well as the lines will be too great. Siemens has built a section 2 km long on the E16 outside Sandviken where a Scania lorry has been operating since June 2016. A similar section was constructed in 2017 to the port of Los Angeles, using Mack trucks and others. Three projects which are, each covering around 5 km, are being planned in Germany, and in agreement has been made to construct one section in Hessen in 2018.

Conductive transmission through rails in the carriageway has not made a great progress in its development. The Rosersbergs Utveckling AB is demonstrating Elways AB's technology on a section 2 km long on road 893 outside Arlanda. As per the reports, Elonroad AB has built a test facility which a few hundred metres long outside Lund as well as planning to carry out the tests in Mariestad which was commencing in 2017. Alstom has developed its tram technology as well as tested that together with the Volvo AB's current collector on a section 300 metres long on the test track in the Hällered. Moreover, inductive technology has been tested by Bombardier on a closed track in Germany. In the case of Korea, the KAIST University has created a model of a technology for the urban buses on a route in the town of Gumi. In the US, five universities involved in the project called SELECT and are working on the inductive technology. According to the schedule, a demonstration will take place using a

5-axle semitrailer in the winter of 2017/18 with the aim of achieving a Technology Readiness Level (TRL) of 6.

4.2 Factors affected in ERS

There are a lot of technological barriers that need to be overcome for dynamic inductive charging to be feasible. The issues below are identified as the most important problems for the inductive ERS manufacturers: A number of systems like, CWD and IPV have the issues synchronising primary coil segments with the vehicle pickup. Synchronisation is affected by vehicle speed, lateral alignment, signal switching and communications speeds; all of which can impact the power transfer rate and overall efficiency.

In the article (Sundelin et al., 2016) have studied the maturity of different dynamic power transfer technologies to be implemented at large scale. Some of the studies like (Grahn, 2014; M. Taljegard et al., 2017) have modelled the electric power demand for roads that using ERS. To illustrate, (Stamati and Bauer, 2013) investigated the possibilities to meet with renewable energy the electricity demand from the highway traffic flow on an average day in the Netherlands. (Taljegard et al., 2017) have studied the spatial and dynamic electricity demand of an ERS in Norway. (F. Chen et al., 2015) have provided an overview of the current status art of ERS, presenting the challenges as well as opportunities associated with ERS. However, (F. Chen et al., 2015) have also pointed out some research gaps, such as the environmental performance of ERS, i.e., the real impact from using ERS to reduce overall energy usage as well as greenhouse gas emissions. Latter will obviously depend on the fuel mix used to generate the electricity required to power the ERS vehicles. In addition, several reports have also assessed different aspects of ERS (e.g., Boer et al. 2013; Connolly, 2016; Olsson, 2013a; Wilson, 2015). In (Wilson et al., 2015) has analysed the feasibility of implementing dynamic wireless power transfer system on the Strategic Road Network in Great Britain. Olsson, (2013a) has studied the different cost and technical aspects of implementing an ERS on a highway in Sweden. From the report of (Den Boer et al., 2013), the costs for different power trains technologies and fuels, including dynamic power transfer, are compared for trucks. Connolly (2016) has compared ERS with oil-driven and battery-electric vehicles in terms of cost, CO_2 emissions, and energy. The study concludes that the ERS will be more cost-competitive than both oil and batteries. The ERS infrastructure will be shared by a large number of vehicles depending on the road traffic volumes like vehicle kilometres and the ERS technology chosen like overhead lines, electric rails or inductive supply. However, implementation of an ERS will require which the new infrastructure is established, which is obviously associated with considerable up-front investment costs. So, it is important that to investigate the factors affecting as well as the benefits of implementing the large-scale ERS including the extent of the road net-work as well as the vehicle types which could be beneficially electrified, based on analyses of the road traffic volumes, the type of roads and infrastructure investment costs as well as CO_2 emissions potential. As per the study initiated by the Swedish government on how the transportation sector will be made fossil-free reveals which electrification has the potential to play an immediate role in reducing the fossil fuel dependence of the Swedish transportation sector (Johnsson et al., 2019).

There are number of inductive systems have low power ratings, basically around 20kW which are only suitable to light duty vehicles. To power larger vehicles, power levels, efficiencies as well as misalignments need to be improved. This is especially relevant given the findings of which conclude the only feasible near-term applications of electric road systems are for metropolitan bus schemes as well as freight corridors (short-long-international haul). At the present levels of development inductive systems are only capable for delivering the power to vehicle and the speeds of approximately 80-100km/h, which is same for the trucks which have the maximum highway speed of 90km/h in most states, but this is not suitable for the passenger vehicles which would basically travel much faster (up to 120-130km/h).

Moreover, the other important issue which needs to addressing is the ability of multiple vehicles to Charge on a single segment or coil section. This case is related to the synchronisation of coils as well as their communication speeds. Other factors that limit efficiencies as well as power levels among systems that include IPR; installation depths (similar air gap); system architectures; ERS geometry (coil size, dimensions); electrical as well as electromagnetic requirements for conductive and inductive ERS respectively. On review of technical feasibility of conductive ERS, there are many technological barriers which need to be overcome for some of the systems. The issues below are identified as the most important issues for conductive ERS manufacturers: For this conductive rail (inroad) ERS, there are lot of systems which have issues with the system that creating a raised surface profile in the carriageway. Changes in the surface profile is the main risk to the drivers as well as motorcyclists.

The number of conductive rail systems which use electrified rails that have a very different friction level to the adjacent road surfacing. To ensure the safety of road users, the skid resistance of the rails must meet the requirements of the road surfacing for different types of roads (primary and secondary routes). For the conductive overhead ERS, the systems are restricted to HGVs as well as buses. The challenge for conductive overhead ERS is to create their system suitable for all types of electric vehicles. Conductive overhead systems are also limited to open roads and motorways; tunnels, bridges and roads with any overhead infrastructure would not be suitable for these systems; The Honda system is limited to roads with VRS; therefore roads with no VRS, and any roads with hard shoulders or emergency stop lanes (all motorways) would not be deemed suitable for this system**.**

Chapter 5

METHODOLOGY

The main objective and focus were to conduct a state-of-the-art review on different systems of ERS, their TRLs, and the key player involved in the development of these technologies as well as the business perspective. A literature review was carried out to gather and summarise the most recent information as well as research findings on ERS solutions from around the world. Information has been consolidated from previous ERS reports and is enhanced through a comprehensive evaluation of journals, articles, research projects, news articles, academic thesis's, demonstration results, and manufacturer information. The articles and journals are also taken from the university library database (scopes).

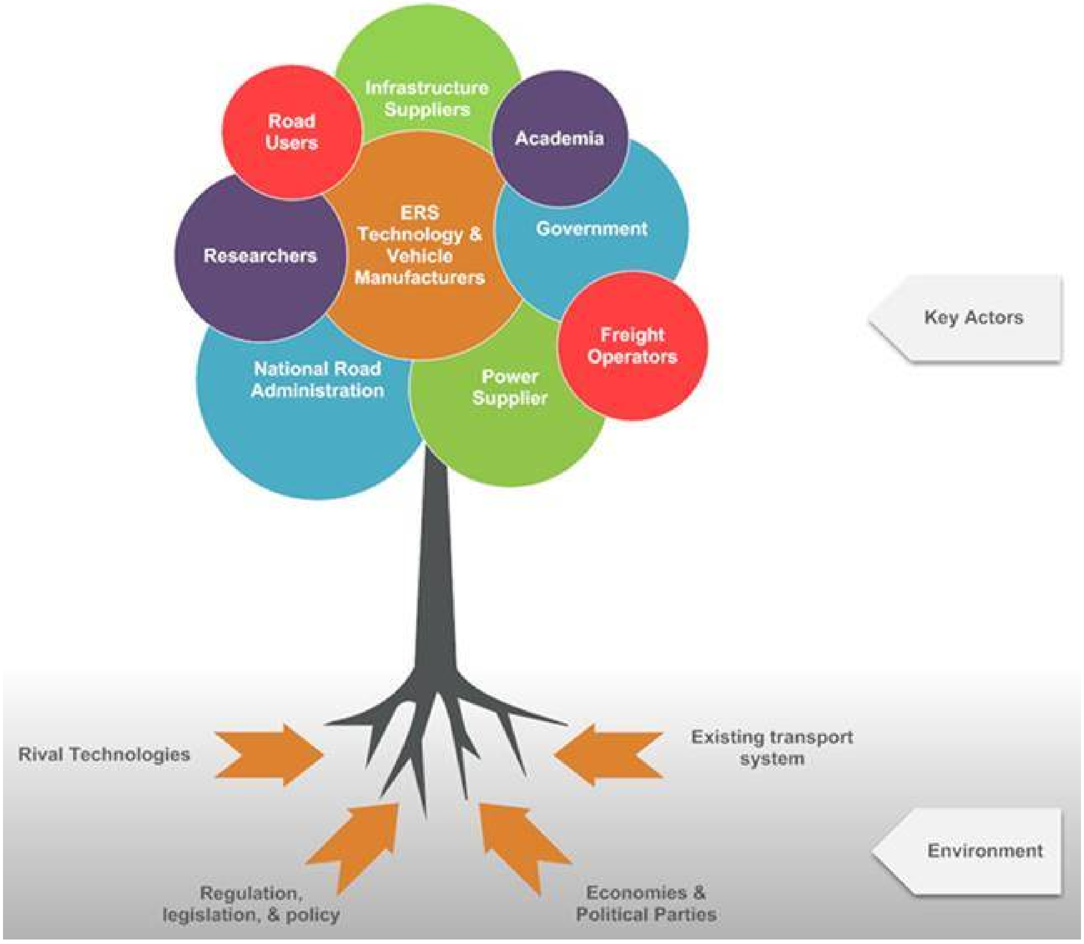


Figure 5.1 ERS development

Including with this, some relevant information gathered from the sites of different road administrations and government bodies; information of ERS developers; researchers and academics; freight operators; power suppliers.

In this report the important advantages and disadvantages of the ERS concepts gathered and discussed. Every ERS concept was assessed in relation to the areas that listed below. Based on the information available, the advantages, disadvantages as well as the potential impacts of every system were identified and highlighting the elements relevant to road administrations. The main areas for evaluation were:

- Technical feasibility
- Factors and different influences in the development of ERS
- Developments of ERS in global perspective
- Business and market perspectives.

The thesis is mainly focusing to review and explore the available information on the current developments of ERS in developed countries. Nowadays all EV vehicle companies are using the inductive charging method, but this method can only charge the same company vehicles. The motor coil used by the company is different because this can produce more power than the other company EV vehicle. This will reflect in their charger also there for the charger will not set for another company vehicle. In our research area, we are trying to identify the coil discerption of all vehicles and identify what type of charging coil can use to charge all kinds of electric motors that should be standardized. This standardized coil can be transferred the power to any kind of vehicle like the light vehicle as well as the heavy vehicle on the road. The electric vehicle can charge by the coils which are embedded in the road. These coils can give power to the vehicle with no time while driving on the coil. This process is monitored by the power grids placed within a particular interval of distance. This will rectify the problem of recharging and lack of battery backup and it also reduces the emission of CO2 from the vehicles as well as reduce the demand for fossil fuels.

In addition, more information collected from the interview participants from different areas related to this system, also there are many information gathered from the interviews which is uploaded in the YouTube as well as the documentaries related to the development of ERS and EVs. These were shortlisted based on latest updates and relevant reports, country of operation, and type of ERS system. The aim of this activity was to provide a data collection for richer discussion on ERS developments, benefits and challenges.

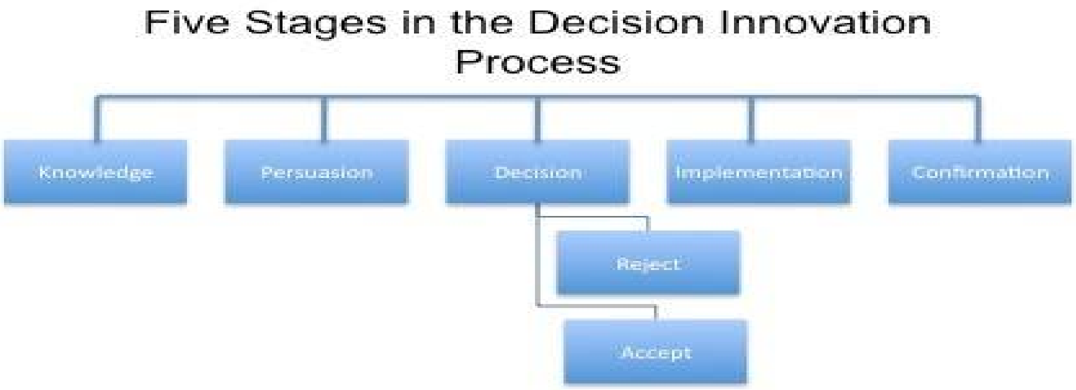


Figure 5.2 Stages of Technology Diffusion Innovation

In this Thesis, Technology Diffusion of Innovation is all about the understanding inclination and factoring in consumer inclination. There are five stages in Technology diffusion innovation they are Knowledge, Persuasion, Decision, Implementation and Confirmation

Knowledge: It is the initial point of an innovation, this will collect the data from the customer, collect modern idea and product service this will help to gain more knowledge. After this the product draw back will scrutinise and make the product to more efficient.

Persuasion: after gaining the knowledge about the product how it will be utilised for the customers.

Decision: the diffusion of innovation theory it’s the time for the decision whether it can be useful for the customer or not if there is any defect or drawback in the product then it will be rejected otherwise the product will be installed.

Implementation: after the installation the customer will give the feedback whether this system is useful or not, depends on the feedback if there is any updating recurred then it will be completed then this system will be in regular use.

Conformation: In this part the customer will give more support to customise the system in all the manner.

Chapter 6

ELECTRIC VEHICLE BATTERY RANGE

The EV tradition is developing awesome philosophies, each pleasant a special user group. This is visible with vehicle sizes and the related batteries. The subcompact EV comes with a battery that has 12–18kWh, the mid-sized household sedan has a 22–32kWh pack, and the luxury models through Tesla stand by myself with an oversized battery boasting 60–100kWh to provide prolonged riding range and attain high performance. The EV is stated to replace vehicles with the internal combustion engine (ICE) through 2040. Several technological improvements will be wished to make the electric powertrain sensible and economical. Even with oil at $100 a barrel, the rate of the EV batteries would want to fall by using a thing of three and additionally provide ultra-fast charging. In terms of carbon footprint, the electricity used to power the EVs would want to come from renewable sources. Published reports say that emissions from EVs powered by means of America’s electrical energy grids are higher than these from an environment friendly ICE (“BU-1003: Electric Vehicle (EV) – Battery University,” n.d., p. 1003). Table 6.1 illustrates frequent EVs1.

The makers of Nissan Leaf, BMW i3 and different EVs use the demonstrated lithium-manganese (LMO)battery with an NMC blend, packaged in a prismatic cell. (NMC stands for nickel, manganese, cobalt.) Tesla makes use of NCA (nickel, cobalt, aluminium) in the 18650 mobile that supplies a spectacular precise strength of 3.4Ah per phone or 248Wh/kg. To defend the refined Li-ion from over-loading at dual carriageway speed, Tesla over-sizes the pack with the aid of a magnitude of three to 4-fold in contrast to different EVs. The massive 90kWh battery of the Tesla S Model (2015) offers an unparalleled using vary of 424km (265 miles), however the battery weighs 540kg (1,200 lb), and this will increase the power consumption to 238Wh/km (380Wh/mile), one of the perfect among EVs. In comparison, the BMW i3 is one of the lightest EVs and has a low electricity consumption of 160Wh/km (260Wh/mile). The vehicle makes use of an LMO/NMC battery that affords a reasonable unique electricity of 120Wh/kg however is very rugged. The mid-sized 22kWh pack gives a using vary of 130–160km (80–100 miles). To compensate for the shorter range, the i3 affords REX, a non-compulsory fuel engine that is equipped on the back. Table three compares the battery measurement and power consumption of frequent EVs. The vary is below ordinary non-optimized using conditions (“BU-1003: Electric Vehicle (EV) – Battery University,” n.d.).

Model	Battery	Charge Times
Toyota Prius PHEV	4.4kWh Li-ion, 18km (11 miles) all-electric range	3h at 115VAC 15A. 1.5h at 230VAC 15A
Chevy Volt PHEV	16kWh, Li-manganese/NMC, liquid cooled, 181kg (400 lb), all electric range 64km (40 miles)	10h at 115VAC, 15A. 4h at 230VAC, 15A
Mitsubishi iMiEV	16kWh; 88 cells, 4-cell modules; Li-ion; 109Wh/kg; 330V, range 128km (80 miles)	13h at 115VAC 15A. 7h at 230VAC 15A
Smart Fortwo ED	16.5kWh; 18650 Li-ion, driving range 136km (85 miles)	8h at 115VAC, 15A. 3.5h at 230VAC, 15A
BMW i3 Curb 1,365kg ((3,000 lb)	Since 2019: 42kWh, LMO/NMC, large 60A prismatic cells, battery weighs 270kg (595 lb) driving range: EPA 246 (154 mi); NEDC 345km (215 mi); WLTP 285 (178 mi)	11kW on-board AC charger; ~4h charge. 50kW DC charge; 30 min charge.
Nissan Leaf*	30kWh; Li-manganese, 192 cells; air cooled; 272kg (600 lb), driving range up to 250km (156 miles)	8h at 230VAC, 15A 4h at 230VAC, 30A
Tesla S* Curb 2,100kg (4,630 lb)	70kWh and 90kWh, 18650 NCA cells of 3.4Ah; liquid cooled; 90kWh pack has 7,616 cells; battery weighs 540kg (1,200 lb); S 85 has up to 424km range (265 mi)	9h with 10kW charger; 120kW Supercharger, 80% charge in 30 min
Tesla 3 Curb 1,872 kg (4072 lb)	Since 2018, 75kWh battery, driving range 496km (310 mi); 346hp engine, energy consumption 15kWh /100km (24kWh/mi)	11.5kW on-board AC charger; DC charge 30 min
Chevy Bolt Curb 1,616kg; battery 440kg	60kWh; 288 cells in 96s3p format, EPA driving rate 383km (238 miles); liquid cooled: 200hp electric motor (150kW)	40h at 115VAC, 15A. 10h at 230VAC, 30A 1h with 50kWh

Table 6.1 Illustrates the frequency and range of different Vehicles

Instructions of battery (“BU-1003: Electric Vehicle (EV) – Battery University,” n.d.):

Life Time: Most of the company EV batteries are assured for 8 years or 160,000km (100,000 miles). Due to the climatic condition its life will Varey, during the hot climates speed up ability loss; inadequate facts are on hand about how batteries age below distinctive climates and utilization patterns

Assurance: Burdens occur if the battery is misused and is saved past its life time. Similar fears befell 150 years in the past when steam boilers exploded and fuel tanks burst. A cautiously designed BMS assures that the battery operates inside a secure working vary

Cost: This offers a major disadvantage as the battery consists of the fee of a small automobile powered through an ICE. BMS, battery cooling, heating and the eight-year assurance add to the cost.

Performance: Unlike an ICE that works over a huge temperature range, batteries are touchy to warmth and bloodless and require local weather control. Heat reduces the life, and bloodless lowers the overall performance temporarily. The battery additionally heats and cools the cabin.

Specific energy: In phrases of calorific price per weight, a battery generates solely 1 percentage of what fossil gas produces. One kilogram (1.4 litre, 0.37 gallons) of fuel gives roughly 12kWh of energy output, whereas a 1kg battery gives about 150Wh power. However, the electric powered motor works more than 90% efficient when it compares with modern ICE comes in at about 25 percent only.

Specific power: The electric driving system has higher torque with the constant horsepower than the ICE. This is will give more power while the vehicle is in acceleration.

6.1 Different types of Battery Charging method

There are several ways in which battery electric powered motors can be charged with the aid of plug-in charging. five 'modes' of charging technological know-how are commonly available. Each of them can contain one of a kind mixtures of energy degree provided by using the charging station (expressed in kW), types of electric power used (alternating (AC) or direct (DC) current), and plug types. The energy level of the charging supply relies upon on each the voltage and current from the electricity supply. Dipnet on this how faster a battery can be charged. The power used to charge the battery levels widely, from 3.3 kW to 120 kW. Lower electricity tiers are traditional of residential charging points (Europæiske Miljøagentur, 2016).

Slow Charging: Permits car charging using frequent family sockets and cables. It is often determined in home or office buildings. The ordinary charging strength degree is 2.3 kW. Household sockets gives AC power only

Slow or Semi Fast Charging: also uses a non-dedicated socket, however with a special charging cable supplied by way of the car manufacturer. A safety machine that is built into the cable affords safety to the electrical installations. It presents AC supply only.

Power,	Current	Type	Time for charging	Charging Location
120 kW	DC	Fast Charging, Inductive charging	10 Minutes	Motorway service area or dedicated charging station in urban area
50 kW	DC	Fast Charging, Inductive charging	20-30 Minutes	Motorway service area or dedicated charging station in urban area
22 kW	AC Three Phase	Semi- Fast or fast charging	1-2 Hours	Most Public Charging poles
10 kW	AC Three Phase	Semi- Fast or fast charging	2-3 Hours	Household, Work place wall Box
10 kW	AC Three Phase	Semi- Fast or fast charging	2-3 Hours	Household, Work place wall Box
	AC to DC	Inductive charging		
7.4 kW	AC Single Phase	Slow charging, Semi-fast Charging	3-4 Hours	Public Charging Poles
	AC to DC	Inductive charging		
3.3 kW	AC Single Phase	Slow charging, Semi-fast Charging	6 -8 Hours	Household, work place wall box
	AC to DC	Inductive charging		

Table 6.2 Power transfer rate and the time consumption to charge the battery

Slow, Semi-Fast or Speedy Charging: uses a one-of-a-kind plug socket and a devoted circuit to enable charging at higher strength levels. The charging can be both by using a field geared up to the wall (wall box), typically used at residential locations, or at a stand-alone pole, regularly seen in public locations. It makes use of committed charging equipment to make certain secure operation, and provides AC current.

Fast Charging: Additionally, sometimes referred to 'off-board charging', can provide DC current to the vehicle. An AC/DC converter is located in the charging equipment, alternatively of inside the car as for the different levels. One drawback of high-power, speedy charging is that the improved currents imply that more electricity is misplaced at some stage in transfer, i.e. the efficiency is lower. Moreover, speedy charging can decrease battery lifetime, lowering the range of total charging cycles. Fast DC charging factors are also around three times as high-priced to deploy as a simple AC charger, so many customers are reluctant to make investments in the extra costs. While some new electric automobile fashions are furnished with a DC charging facility, others require the purchase of an extra charging gadget Electricity can be dispensed the use of single-phase or three-phase systems. Households commonly use single-phase strength for lights and powering appliances. It lets in solely a restricted power load. Commercial premises regularly use a three-phase system, as it gives greater power.

Inductive Charging: This is also known as wireless charging; this system does not require any physical contact between the charger and vehicle. Instead of that the charger will create an electromagnetic filed around a charging pad which is activated when an electric vehicle with a corresponding pad is positioned above it. The inductive method currently operates at only a selected few pilot location now this system is going to commercialise in some countries. The inductive power transfer system will increase the frequency to improve the power transfer capability. The capacitors connected to the coils to create a resonant system that will improve the efficiency of charging system.

6.2 Wireless Technology In ERS

It must be possible to provide either low-voltage power (1000 volts) or high voltage power (16,000 volts) to vehicles. The low-voltage option involves lower vehicle costs but higher infrastructure costs. The opposite is true for the high-voltage option. The electric road systems currently being developed are all of low-voltage type. Both AC and DC voltage systems are being tested. The Swedish Transport Administration is of the opinion that low-voltage systems will be tested over the next five years. Current from the public power distribution grid will need to be transformed in batches in order to power vehicles. This takes place over three stages:

- A high-voltage grid parallel to the road, in or near to the road area, will probably need to be constructed as there is normally no existing grid for connection points to a sufficient extent.

- Transformer stations, which convert high voltage into low voltage, need to be constructed every two or three km along the road, it depends on the road traffic condition.

- Low-voltage grids for final distribution to vehicles need to be constructed in accordance with the design of the technology in question.

The identity of the proprietor of the electric road system needs to be investigated. However, it is important for the International Transport Administration, in its role as the road owner, to have access to the electric road system facilities for the purposes of operation and maintenance of the road infrastructure.

6.3 Inductive charging system:

In future electric vehicle can drive to a long distance without ever needing to stope to recharge its battery. Instead, power generation by wind and solar resources is delivered wireless from the roadways to the vehicle when it's in motion. Not halting for recharging will make EVs really self-governing, and, on the grounds that the vehicles would thus be able to stay in administration for additional hours, less vehicles will be expected to fulfil traveller need. Moreover, EVs with moving (dynamic) remote charging can have a lot of littler batteries, an alternative that can decrease their cost and quicken appropriation.

6.4 Wireless power transition

In the present scenario there are two types of inductive charging system are used they are 1) magnetic coil coupling between conducting coil and capacitive, this will transfer energy to the electric field coupling between conducting plate figure 6.1. This is applicable for medium range, Inductive WPT (Inductive wireless power transfer) system has traditionally been preferred. 2) capacitive wireless power transfer system in this the power will be transferred from a comprising high frequency inverter and the rectifier with semiconductor device. figure 6.2 (Collin et al., 2019)

6.4.1 Inductive wireless power transfer (Static and Dynamic)

From the last few decades has seen a tremendous progress in the inductive WPT technology is using for the electric vehicle stationary charging. Now a day's stationery charging is already available and some manufacturing company have implemented built- in inductive stationery charging system from 2018 onwards. In inductive charging system the magnetic flux guidance and shielding require ferrite cores, making them very costly. In a 50Kw inductive WPT system was develop at 25 kHz frequency. By attaining resonance coil using power switching, the damage was minimized by zero current switching and implementing the control system, this system will give permeation to accommodate vehicle with different parameters. Wireless transfer system with 100KW system for electric vehicle operating at 22KHz was conducted in

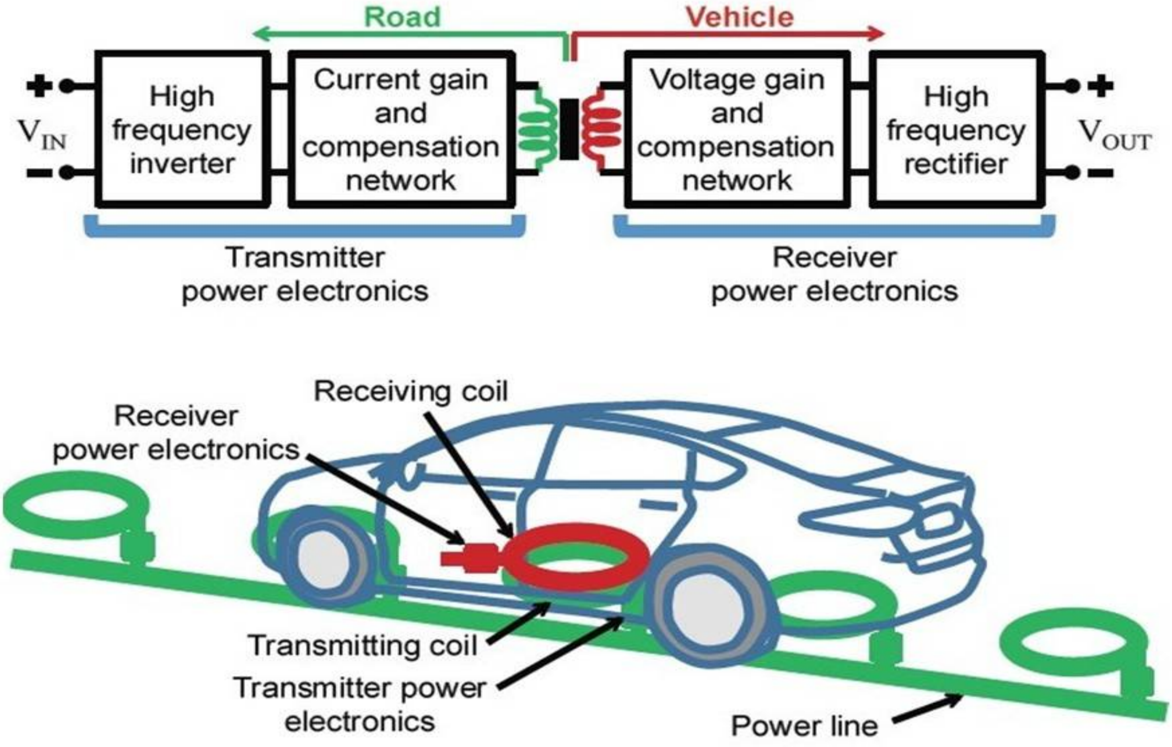


Figure 6.1 Inductive wireless power transfer

a 12 cm distance, this test results about 96% of efficiency and this system is a very bulky. To limit the losses in the weights, the operating frequencies of these systems are coming under 100KHz, come from large coils and low power transfer densities. The cost of this system is very high but the power transfer density is particularly problematic for dynamic WPT, this system requires very high-power capability for transfer required energy to the vehicle while its very short time passing over a charging coil. Due to this the dynamic inductive WPT is yet to become communally feasible, although a smaller number of systems have been experimented (Collin et al., 2019; “Wireless Charging of Electric Vehicles,” 2018).

6.4.2 Capacitive WPT System (Static and Dynamic):

Capacitive system has a high probable advantage over the inductive system due to the relatively directed nature of electric fields, this reduce the demand of electromagnetic field covering. Capacitive WPT system does not use ferrites, they can be operated at higher frequencies, allowing them to small and less expensive. Capacitive WPT system then implements dynamic EV charging systems. This is using because the distance between the road and electric plates is very small, effective power transfer will occur only at very high frequencies, this will reflect while the designing the vehicle charging system it’s a challenging one. With the recent availability of wide bandgap, the power transfer through semiconductor devises that help them

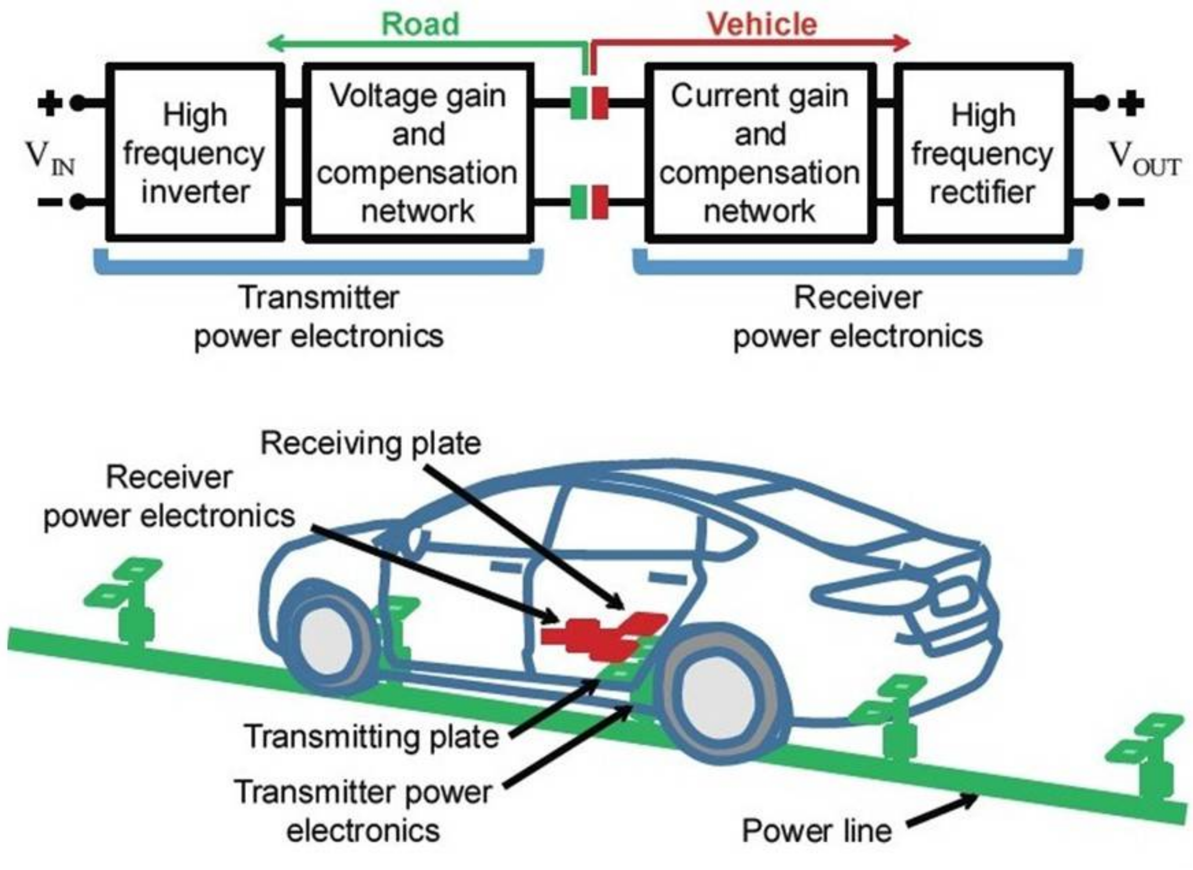


Figure 6.2 Capacitive wireless power transfer.

to give high frequency operation. The energy density of a capacitive charging is 2 kW/m2, which is smaller than the almost 40 kW/m2 of the inductive charging system. This is due to the fact the coupling capacitance is normally in the PF vary when the switch distance is in the 100 of mm range. The active way to make bigger electricity density is to expand the plate voltage and the switching frequency. Second, the capacitive charging gadget can realise a DC-DC effectivity of 91.6% for electric powered car charging system, whilst a DC-DC effectivity of 97% can be accomplished in an inductive charging gadget. Since the switching frequency is normally higher than 1 MHz, the pores and skin impact of the wire will become apparent and greater losses can be brought on. This make the capacitive WPT system more viable. There are some challenges occurs with the capacitive WPT system in EV charging are (a) carry out high power shift density at high efficiencies while meeting the electromagnetic safety requirements. (b) Interning effective power transfer to the couplers in relative position charging. There is the problem that they face in capacitive WPT system (Collin et al., 2019; “Wireless Charging of Electric Vehicles,” 2018).

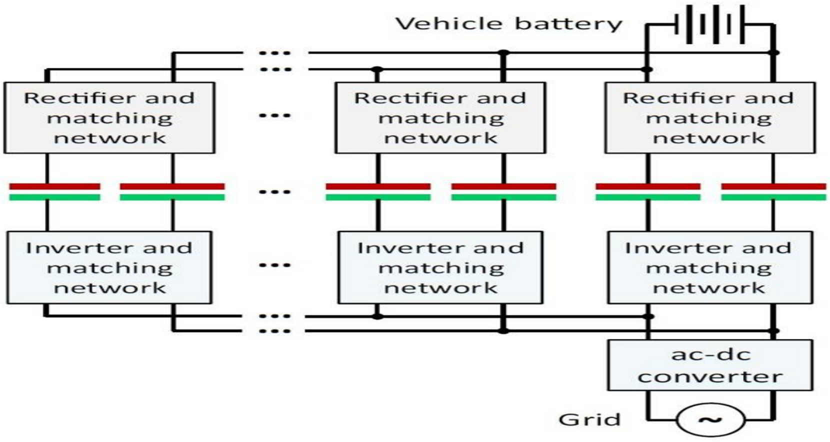
6.5 Protected and Adequate High-Power Transfer

In the wireless power transfer (WPT) system couplers size is reduced and the power transfer density increased by changing the design of the system to operate it in high frequencies. In inductive system, this will increase the inductive voltage by increasing the frequency components for the reduced mutual inductances of the smaller coil, and the capacitive system will increase the displacement current with high frequency compensates for the smaller plates for smaller capacitance. High operating frequency also enable smaller power electronics associated with wireless power transfer system for decreases in energy storage requirements. The problem in this system is getting high efficiencies at high switching frequencies is challenging. The fringing fields of WPT system must be in safe level in areas encaged by the human beings and animals. The requirements for capacitive wireless transfer system required a circuit stage that provide correct voltage and current gain as well as reactive compensation (“Wireless Charging of Electric Vehicles,” 2018).

6.6 Effective Power Transfer in WPT system:

In WPT system the effective power transfer will occur when the system operates close to the resonant frequency of the resonant container formed by the reactance of the coupler and compensating network

The coupler reactance depends on the vehicle’s road clearance, this will vary as the when the vehicles move over the power charger (Fig 6.3). The drift between the resonant and frequency movement, a reduction in transfer of power and wireless power transfer system efficiency. In WPT system it operates is 100 kHz frequencies and below, bandwidth is not restrictive, this system will change the resonant frequency while in operation it depends on the type of vehicle. This system has high frequency WPT system, this system will operate as per the designed high frequency. There is one mothered that can use in low power inductive WPT system, that is use a bank of capacitors that can switched in and out of the compensating network, to keep the resonant for unchanged frequency as transmitter and receiver move relative to each other. But this will not be effective in High power WPT system because this system will take a high frequency so for switching this system it requires bigger switches its more expensive. This strategy is additionally less ideal to capacitive WPT due to the fact it requires a couple of



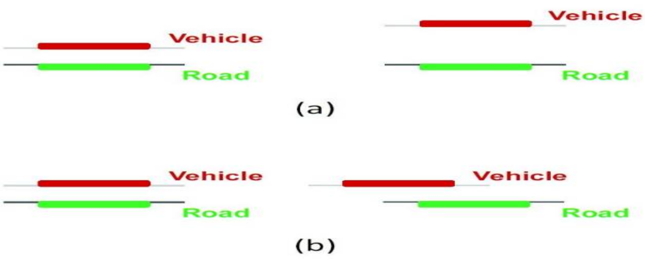


Figure 6.3 a) variation in coupling due to the different vehicle road clearances b) variation in coupling due to change in the vehicle position as it drives over charger.

compensating inductors, which are better than capacitors. By accurately controlling the output voltages of its two coupled rectifiers, the AVR can supply always variable compensation while maintaining most effective smooth switching to make sure high efficiency (Fig 6.3). This compensation architecture ensures that the output energy of the WPT system is maintained at a constant level across large versions in coupling and is relevant to both capacitive and inductive WPT systems (“Wireless Charging of Electric Vehicles,” 2018).

Chapter 7

ELECTRIC ROAD SYSTEM - INTERNATIONAL OUTLOOK

If we examine a number of projects implemented in various cities around the world, we can see how the nature as well as extent of public intervention have changed considerably. The article (Alfred Wiederer, 2010) present case studies in four cities that have run pilot schemes for the introduction of electric vehicles also that provide examples of the roles that the public sector might adopt. In this section, investigating the resent developments of ERS technology in a global perspective and understanding the competitors of electric road system all over the world. As per the recent updates, Sweden has a leading role in the testing of electric road technology as well as demonstrators in electrified roads also introduced the world's first electric road on public roads outside Sandviken in 2016. However, there are many countries those who engaged in research and development on ERS. Countries like, Germany, the United States, South Korea, Israel and Spain are more focused within the field. The report (Jordi Perdiguero, 2012; Linda Andersson and Kristin Skjuta, 2018) also helped to find out the ERS developments in some countries which are listed below.

- Singapore, initiated a project to invest 20 million dollars in the setting up of a comprehensive network of the recharging points as well as to provide subsidies for the purchase of electric vehicles in June 2010. The primary goal of local government is to attract the electric car industry to Singapore (Jordi Perdiguero, 2012).

- In the City of London, the scheme has entailed a 17million pound investment, including the installation of a network of charging stations, the electrification of its public transport fleet and incentives for purchasing and marketing electric vehicles. To develop this ambitious project (submitted in May 2009), the city council’s transit agency “Transport for London” is working with a consortium of electric vehicle manufacturers, major utilities in London and car rental companies (Jordi Perdiguero, 2012).

- The City of Berlin has initiated two simultaneous electric vehicle programs, both powered and funded by private industry. The city is administratively limited to helping companies and ensuring the compatibility of the two offers as far as the charging network is concerned (Jordi Perdiguero, 2012).

It is interesting to note how the pilot projects run in these cities have given different emphases to the deployment of electric vehicles: industrialization, in the case of Singapore; full network development, in the case of London; and the recharging network, in the case of

Berlin. Likewise, the degree of public sector involvement varies significantly from one project to another: from simple guidelines for private companies (the case of Bangalore and Berlin) to an active role in the market though heavy investment (the case of Singapore and London) (Jordi Perdiguero, 2012). To evidence more, Sweden currently has a leading role in testing electric road technology and demonstrators in electrified roads and introduced the world's first electric road on public roads outside Sandvik in 2016. However, several other countries are engaged in research and development within the field. Previous studies highlight several countries, including Germany, the United States, South Korea, Israel and Spain.

7.1 Germany

Germany is at the forefront in the development of electric roads. Projects are being conducted in several of the aforementioned technologies: Bombardier is researching into inductive power transmission and has developed a system integrated into a Scania truck that they are testing on an 80-metre test track in 14 Mannheim. Germany has three upcoming projects in overhead transmission. Amongst other things, the government has financed three projects where the technology shall be installed on three sections of public road in 2018 and 2019 (Linda Andersson and Kristin Skjuta, 2018).

7.2 South Korea

KAIST University has been conducting research and development in inductive power transmission through the OLEV company since 2008. A solution for buses on public roads is being tested there with two buses in operation, powered by an inductive electric road (Linda Andersson and Kristin Skjuta, 2018).

7.3 Israel

A small Israeli start-up referred to as Electreon has some other idea: electrify the roads to recharge vehicles as they are driven. At its check web page on a boarding faculty campus backyard Tel Aviv, the enterprise has positioned copper coils under 900 feet of round pavement that transmit recharging wireless power to an electric powered Renault Zoe check automobile as its drivers by. Electreon has a 30-metre long test track for inductive transmission in Caesarea, and there are plans to test the technology in Tel Aviv on an 800-metre long public transport route during 2018 (Linda Andersson and Kristin Skjuta, 2018).

7.4 USA

During the summer of 2017 a test facility was started, similar to the Siemens facility outside Sandviken, with conductive transmission via overhead power lines. The test section of road was 1.6 km and located outside Los Angeles. Five universities are conducting joint research into inductive transmission in a so-called SELECT centre (Linda Andersson and Kristin Skjuta, 2018).

7.5 Spain

In Malaga, an EU project in inductive power transmission project has been conducted. The project was based on a self-driving electric bus that was charged on a 100-metre section of road using inductive power transmission. The work comprises collaboration between the CIRCE and Gulliver companies (Linda Andersson and Kristin Skjuta, 2018).

7.6 Japan

Electric road technology is being developed and tested in Japan based on conductive transmission from the side. Honda is driving the development and is testing the technology at NPVspeeds of up to 150 km/h with a power output of 450 kW, supplied from a large-scale battery system (Linda Andersson and Kristin Skjuta, 2018).

7.7 India

India has the second largest road network across the world almost 5.4 million km. This road network transports more than 60 per cent of all goods in the country as well as 85 per cent of India’s total passenger traffic. The road transportation has gradually increased over the years with the developments in connectivity between cities, towns as well as villages in the country. The Indian roads carry almost 90 per cent of the country’s passenger traffic as well as around 65 per cent of its freight. In India sales of automobiles as well as movement of freight by roads is growing at a rapid rate. The Indian city of Bangalore has no specific plan to promote electric vehicles, yet there are over a thousand electric vehicles of the REVA brand (a domestic producer) on the streets. This seems to indicate that, at least in this particular case, there is no need for active intervention on the part of the public authorities to promote demand for electric vehicles (Jordi Perdiguero, 2012). The transport infrastructure sector in India is expected to grow at 6.1 per cent in real terms in 2017 and at a Compounded Annual Growth Rate (CAGR) of 5.9% by the year of 2021 and thereby becoming the fastest-expanding component of the country's infrastructure sector.

(a) Future expectations

India has great expectations of achieving a better level of penetration in the e-mobility by 2030. The reason is not very surprising; the alarming levels of pollution indices which keep on rising and the colossal dollars the country must pay for annual crude oil imports. In December 2017, New Delhi was in a state of red alert and came close to Beijing in terms of pollution toxicity, such are the pollution indices in India. If India successfully manages to achieve this target by 2030, it could save about 1 Giga Tone of emissions.

Despite lack of specific pointers towards electrification, the EV Industry in India will still take another few year to evolve. This does not owe to the Indian Government's ambitions targets and their resultant steps but simply because the automobile industry believes that India too will follow the low-carbon footsteps which are taking by the global big car markets like China, US as well as Japan.

As the Indian government aggressively pushing towards becoming an electric vehicle market, there will be a requirement for new as well as pollution free efficient vehicle components such as high-density batteries. This can also create a need to set up a global technology centre in the motors design as well as manufacturing space. All these once established by 2030, as per government deadline, will create job opportunities as well as help economy rise. The government has already taken the lead and is promoting Power PSUs to take the lead in setting up EV charging infrastructure in the country. The EV charging infrastructure would need large investments. Renault India MD Sumit Sawhney said, if the government want it to come fast, then they need to start creating infrastructure, clear policy, as well as ecosystem.

Chapter 8

ERS- STANDARDS AND REGULATIONS

This is a legal framework which underpins parallel development lines like, automation, sharing economy, digitization, electrification, and that takes into account the need for efficiency and the impact of regulations in community planning. This is important even at this stage to consider and investigate whether there is any need for changes to existing regulations in order to achieve optimum design of facilities that to electric road systems, along with their funding, ownership and operation. Besides the legal considerations the construction as well as operation of electric road systems will bring to the fore other legal issues which could give rise to the need to make amendments to the law. This may relate to factors such as issues relating to liability for damages, processing personal data, planning procedures or building permits, site protection as well as safety requirements for facilities. To be able to carry out a more in-depth analysis of the regulations, the operation has to be concretized to some extent. It is the reason why this is an introductory, general analysis that aims mainly to highlight areas as well as issues that should be examined in greater detail.

Development of the electric road system network brings the following main areas to the fore:

- Access to land for the construction of necessary infrastructure
- The need for grid concessions for the construction and use of electrical systems for infrastructure
- Power distribution
- Review of standards

The description below uses separate headings for the criteria regarding land access, construction and operation and power distribution. As regards funding construction, a legal analysis should take place on a rolling basis and in connection with the continued considerations of the various funding models and their applicability. It can already be stated that such an analysis will need to include factors such as the issue of whether the provisions on charges in the Act (2014:52) on infrastructure charges on roads are applicable to the construction of facilities for electric road systems on existing roads.

8.1 Land access

To illustrate it, the Swedish government, through the Swedish Transport Administration (Swedish Transport Administration, 2017), has what is known as right of way for the existing public road network. Right of way arises when the road maintainer earmarks land or other space for a road pursuant to an established road plan or, in special cases, pursuant to a written agreement. Making it possible to guarantee land access for necessary infrastructure for the electric road system network by means of right of way, just as for the present road network, is a reasonable starting point. Whether it is possible solely to rely on right of way is uncertain, however, and it will probably be necessary to review and partly amend the regulations stating whether it should be possible to rely on right of way in order to obtain land access for the whole of the necessary infrastructure. To be able to obtain right way to land needed for the facilities in question, these must be covered by the definition of the road equipment in the Roads Act, i.e. an arrangement which is permanently needed for the existence, operation or use of the road. Whether all parts of a facility for transmission of power for vehicle propulsion can be considered to constitute road equipment according to the present definition is uncertain. Transformer stations may be mentioned as an illustration of a part of the facility that may not be included.

Assessment has taken place so that if a new function is added to an existing road, a new road plan will be required. The option of propelling vehicles using electricity through lines does in all probability constitute a new function that will require adoption of a new road plan for relevant sections. How far away from the road itself that road equipment can be positioned is not entirely clear at present. It may be necessary to clarify this and to clarify whether the road equipment must always have physical contact with the road or other road equipment. The distance is significance to the extent of the road plan, also to the issue of which facilities may be covered by the right way as well as the facilities for land can be marked with right way. However, access to land outside the road area must be resolved by means of a voluntary agreement, by obtaining right of way, or by means of an expropriation procedure initiated by the owner of the facility. This is something that should be taken into account and investigated further in connection with considerations relating to land access and funding and future owners of facilities. The issue of government funding may also be brought to the fore if the infrastructure is owned by any party other than the government (Swedish Transport Administration, 2017).

8.2 Standard

The purpose of standardization is primarily to facilitate the industrial production as well as help to bring about a good pace as regards the spread of innovations. Industrial winners and losers are created at the same time. This is the reason why there are frequently conflicts with regard to standardization issues. Standardization also takes place at various technology levels in an innovation process. On the one hand, components and interfaces in technologies can be standardized, which is frequently a technical and industrial process undertaken by standardization committees. On the other, the overall design of electric road systems may be standardized. There is also an international, industrial policy-related aspect to this issue. Which electric road system technologies people believe will become successful on the market, and the extent to which they should be subject to standardization work, is a frequently recurring issue. Different stakeholders have different views in this regard. Countries with a large percentage of transit traffic are in greater need of a pan-European standard for electric road systems in countries which import or export large volumes of their goods through the international waterways. The automotive industry is keen to see appointment of a “champion” among technologies so that efficient production of large vehicle series is made possible. The parties that own or manufacture different electric road systems have the same interest, albeit on the condition that their system is the one that is named the “champion”. People wanting electric road systems in their towns and people wanting electric road systems for transporting the goods do not necessarily share the same view of which system is most appropriate. The requirement specification will vary depending on the choice of technical solutions with regard to how the electric road system will be designed and how power will be transmitted to vehicles. One example of existing rules affected in the event of construction of an electric road system is the fact that there are now more applicable technical regulatory requirements which have to be observed when establishing an electric road system, irrespective of the technical solution (Swedish Transport Administration, 2017).

In the road: bearing capacity, longitudinal evenness, transverse evenness, friction, visibility, adaptation to road markings, electrical safety rules. **Above the road: Clearance**. Height requirements with regard to power along/across the road. Safety zones require necessary safety measures according to the regulations in order to protect road users in the event of collisions or vehicles leaving the road. **At the roadside**: Safety zones require necessary safety measures according to the regulations in order to protect road users in the event of collisions/vehicles leaving the road.

Chapter 9

RESEARCH AND DEVELOPMENT WITH COMMERCIALIZATION ACTIVITIES

Research and development (R&D) are the process which intended to create new or improved technology that can generate a competitive advantage at the business, industry, or national level. Even though the rewards can be very high, the process of technological innovation (of that R&D is the first phase) is complex and risky. In addition to this, the originator of R&D cannot appropriate all the benefits of its innovations as well as have to share them with customers, the public, and even competitors. For these reasons, a company's R&D efforts should be carefully organized, controlled, evaluated, as well as managed. In the case of ERS development, R&D works are taking place in many countries with the collaborations of governments, universities, industries, and so forth. This paper is discussing below about some of the R&D ongoing projects globally on ERS

9.1 PATH

Number of papers which include (F. Chen et al., 2015; Palen et al., 2000; Shladover, 2007; Suh and Cho, 2017) indicate that the Partners for Advanced Transit and Highways (PATH) project, led by researchers the first working prototype of the wireless charging EV developed at the University of California, Berkeley. A systematic pilot test of the dynamic wireless charging EV solutions was performed throughout the year of 1980s as well as 1990s. Its wireless transferred power capacity was 60 kW, as well as the operational frequencies of the inductive power transfer were 400 and 8500 Hz, achieving a maximal measured efficiency level of 60% with an air gap of 2–3 in. (Suh et al., 2011) (Kim et al., 2013; Shladover, 2007). Although the project demonstrated the possibility of WPT applications for transportation, it did not lead to a commercialization, owing to its low power transfer efficiency as well as the economic infeasibility of the requisite infrastructural overhauls at the time.

9.2 KAIST-OLEV

The first commercialized dynamic wireless charging bus is the On-Line Electric Vehicle (OLEV), developed by KAIST (Ahn et al., 2013; Kim et al., 2013; Onar et al., 2016; Suh and Cho, 2017). The OLEV adopts a technology called Shaped Magnetic Field in Resonance (SMFIR), which effectively magnifies the electric waves, as well as has achieved the charging efficiencies of up to 80%. The design concept of the OLEV was first presented in a plenary presentation at the 2010 CIRP Design Conference (Suh et al., 2011). Since the first demonstration in 2009, the OLEV system has thus far been deployed at four sites in South Korea. The OLEV trolley originally installed in Seoul Grand Park as a pilot project in late 2009-early 2010 has been running as a commercial service since 2011. It travels on a 2.2 km circular route around the park, powered by an underground power supply totalling 372.5 m in four segments. In 2012, two OLEV buses serviced the international exhibition Expo 2012 in Yeosu. Two OLEV buses have also been serving as shuttle buses on the KAIST campus in Daejeon since 2012. The route configurations, velocity profiles, as well as other operating conditions are well described in (Jang et al., 2016, 2015). In August 2013, OLEV was installed in the Gumi City and it is one of the largest industrial cities in South Korea. The 35 km route is serviced by six buses as well as powered by six charging pads under the road (Jeong et al., 2015).

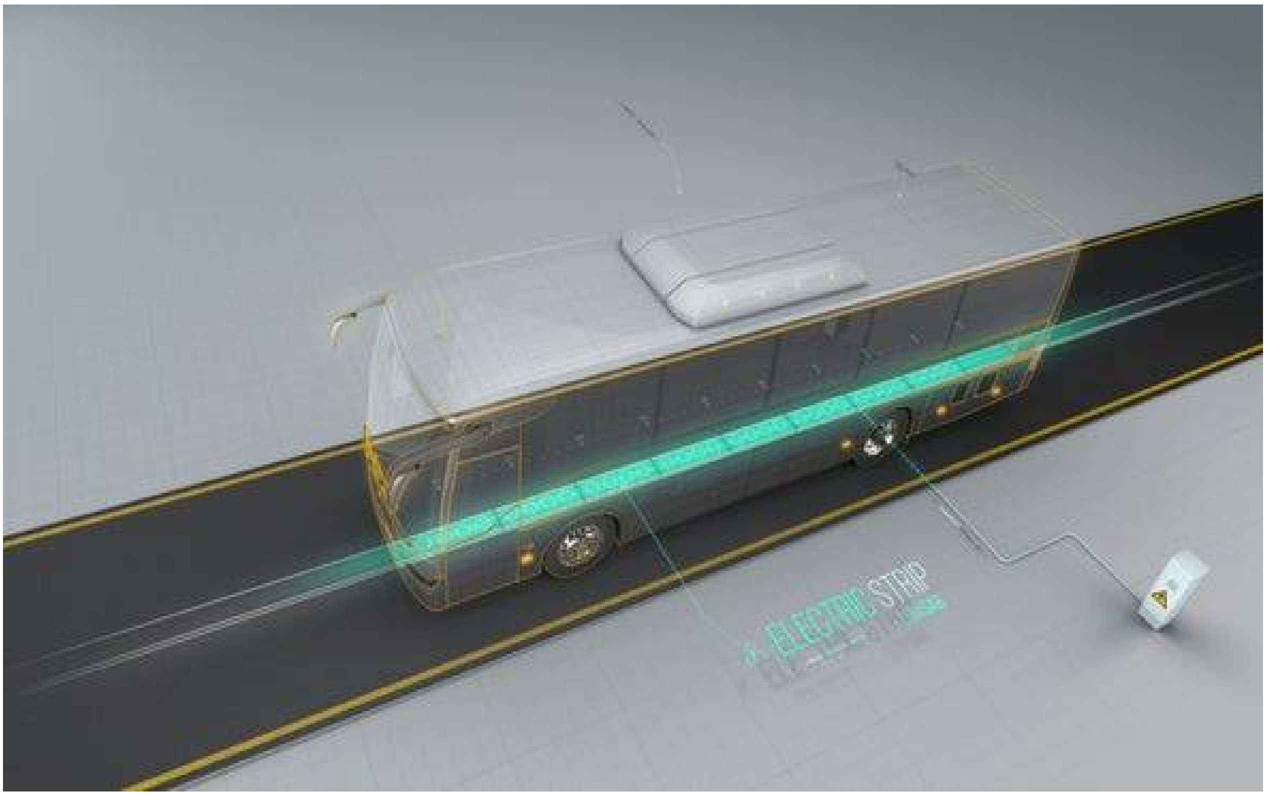


Figure 9.1 Model of Electric bus (wireless charging)

Gumi added two more OLEV buses to its system in May 2016. The latest site to install an OLEV system is Sejong, a recently developed city that houses many central government offices (Jeong et al., 2015; Ko and Jang, 2013; Suh and Cho, 2017). The Developmental background of the OLEV can be found in Choi et al. (2015), Rim and Mi (n.d.), and Suh and Cho (2017d). The developmental history of SMFIR technology, along with its technical details, can be found in the recent book by Suh and Cho (2017). Moreover, note that there are number of patents on the technologies related to SMFIR and OLEV systems. They provide detailed technical information.

9.3 PRIMOVE

PRIMOVE is the e-mobility unit of Bombardier Transportation, which is one of the largest suppliers in the rail industry. Its wireless charging solution is targeted to light rail, bus, as well as automotive fleet operations. Its solution concentrates on static charging, but it also has dynamic charging capability (England, 2017). Through a partnership with German firms Vision Bus and Gesellschaft mitbeschrnkterHaftung (GmbH), PRIMOVE has developed a mechanical lifting as well as lowering mechanism to extend the onboard pickup coils to achieve the most efficient recharging (Brecher and Arthur, 2014). The PRIMOVE system for buses has been tested as well as deployed in many cities in Europe, including Mannheim and Berlin, Germany, and in Bruges, Belgium (Brecher and Arthur, 2014; Cirimele et al., 2018)

9.4 Utah State University and SELECT

Utah State University is actively performing research on dynamic wireless charging solutions. The university is also the home of SELECT (Sustainable Electrified Transportation Center), a research consortium of five partner universities as well as five affiliate institutions in the United States. SELECT, which was formed at the university in 2016, aims to validate as well as commercialize wireless charging and the supporting technologies through vehicle and roadway-scale demonstration as well as pilot projects. The demonstration track at Utah State University consists of a 400 m test track with 75 m precast trenches as well as power panels for embedding coils. The trenches are easily reconfigurable with different transmitters. The power level of each transmitter is up to 30 kW. The EV bus is equipped with a 60-kWh battery (Tavakoli et al., 2016).

9.5 FABRIC

The FABRIC (feasibility analysis and development of on-road charging solutions for future electric vehicles) is a European consortium of 24 partners including the automakers Renault, Citroen, Peugeot, Fiat, Volvo, as well as Scania, collaborated by the Institute of Communication and Computer Systems (ICCS) in Greece. FABRIC aims to develop, test, as well as evaluate the efficiency of dynamic wireless charging prototypes to assess the feasibility of a wide deployment of dynamic wireless charging solutions (Amditis et al., 2017). During its four-year project period, starting from 2014, dynamic charging solutions on the prototype EVs under development have been tested in three test sites in France, Sweden, and Italy. The tested solutions include systems developed by Qualcomm-Halo, Polito, as well as Saet. The French test site primarily tests the Qualcomm-Halo solution on a 100-m-long charging lane. The Italian site, that consists of a 700-m-long track with a 200-m-long wireless charging infrastructure, tests the Polito as well as Saet systems. This demonstration track is also equipped with a simulation toll collection system as well as smart grid interfaces. The Swedish test site is primarily for a conductive solution for trucks (de blas, 2017). The FABRIC project is on the verge of completion, and significant reports from the project are expected to be released in 2018.

9.6 Oak Ridge National Laboratory

The Oak Ridge National Laboratory (ORNL) is an active institution in the US, performing research on wireless charging EV technology with support from the US Department of Energys Vehicle Technologies Office (VTO) (Brecher and Arthur, 2014). ORNL has partnered with Hyundai America Technical Centre and Toyota Research Institute of North America to develop stationary wireless charging solutions for various passenger vehicle models (Chehab, N, 2016; Onar et al., 2016) ORNL is also doing research and developing quasiand dynamic wireless charging solutions (Brecher and Arthur, 2014). Onar et al., (2016) describes the concept as well as prototype of a WPT solution developed by ORNL as well as the mass transit vision of ORNL.

9.7 UNPLUGGED

UNPLUGGED was a European project-based consortium with a budget of 2.3-million euros, focusing to investigate how integrating wireless charging EVs with urban road systems could improve the convenience as well as sustainability of car-based mobility. The main objective of the UNPLUGGED project was to conduct a feasibility analysis of dynamic en-route charging technologies for long-term EVe range extension (Unplugged, 2015). UNPLUGGED examined the technical feasibility, practical issues, interoperability, user perception, and socio-economic impacts of wireless charging EVs from September 2012 to March 2015. The consortium was supported by the European Union’s Seventh Framework Programme and was led by FKA (Forschungsgesellschaft Kraftfahrwesen. Aachen) and ENIDE Solutions S.L. It included 17 partners from the automotive as well as power supply industries, R&D centers, and transport operators. During the project period, two wireless charging systems were built in Zaragoza and Aachen. These innovative systems went beyond the current state-of-the-art in terms of high-power transfer as they included a 50-kW charging station designed as well as manufactured by CIRCE. The system allowed for smart communication between the vehicle as well as the grid and was in line with the latest inductive charging standards, which considered interoperability. The results as well as outcomes of the project are documented in (Unplugged, 2015).

9.8 VICTORIA

VICTORIA (vehicle initiative consortium transportation operation and road inductive application), is one of the projects associated with FABRIC. The primary goal of the project was to investigate the feasibilities of WPT-based electric vehicle as well as road systems including stationary, quasi-dynamic, and dynamic wireless charging EVs (Jang, 2018). The demonstration system adopted a U-shaped track-type charging infrastructure similar to the one developed at KAIST OLEV. A maximum power transfer of 50 kW has been developed and operated on a 10-km bus route in Malaga, Spain, since December 2014. In the demonstration system, 10 segmented wireless charging infrastructure systems with a total length of 300 m were installed. In the EV bus, a self-guided control system automatically controls the position of the receiving panel, following the centre of the road (Rim and Mi, 2017).

Chapter 10

TECHNOLOGY READINESS LEVEL (TRL) IN ERS

Technology readiness level (TRL) is a method for estimating the maturity of technologies during the acquisition phase of a program. The use of TRL allows consistent, uniform discussions of technical maturity across different types of technologies. A technology's TRL is determined during a Technology Readiness Assessment (TRA) which examines program concepts, technology requirements, as well as demonstrated technology capabilities. TRL is considering in the basis of a scale from 1 to 9 with 9 being the most mature technology. The main and primary purpose of using technology readiness levels is to help management of organizations in making decisions concerning the development and transitioning of technology. This should be viewed as one of several tools which are needed to manage the progress of research and development activity within an organization. Current TRL models are tending to disregard negative as well as obsolescence factors. There have been suggestions made for incorporating such factors into assessments. For the complex technologies that incorporate various development stages, a more detailed scheme called the Technology Readiness Pathway Matrix has been developed going from basic units to applications in society. This tool is aim to show that the readiness level of a technology which is based on a less linear process, on a more complex pathway through its application in the society.

In the case of electric road system stakeholders are also concerned about the maturity of the technology and generally rise the demand for the assessment for TRL. With the background as well as experiences, stakeholders were asked to provide estimates of the technology readiness level (TRL) for each concept as a whole, regardless of manufacturer. Additionally, stakeholders were also asked to estimate the time to deploy (in years), providing an overview of technology readiness levels (D Bateman et al., 2018) which provide the averages of stakeholder estimates for TRL and years to deployment (YTD). This can be seen that on average, stakeholders believed that conductive overhead static charging as well as inductive static charging were the most mature concepts with average TRL’s of 7 (2.3 YTD) and 7 (2.2 YTD) respectively. With regards to dynamic applications inductive and conductive in-road ERS were at a similar level of development, with TRL ratings of 5 (5.5 YTD) and 5 (5.5 YTD). On average, stakeholders believed that the most advanced ERS concept, in terms of development, was the conductive overhead solution, with a TRL rating of 6 (4.1 YTD).

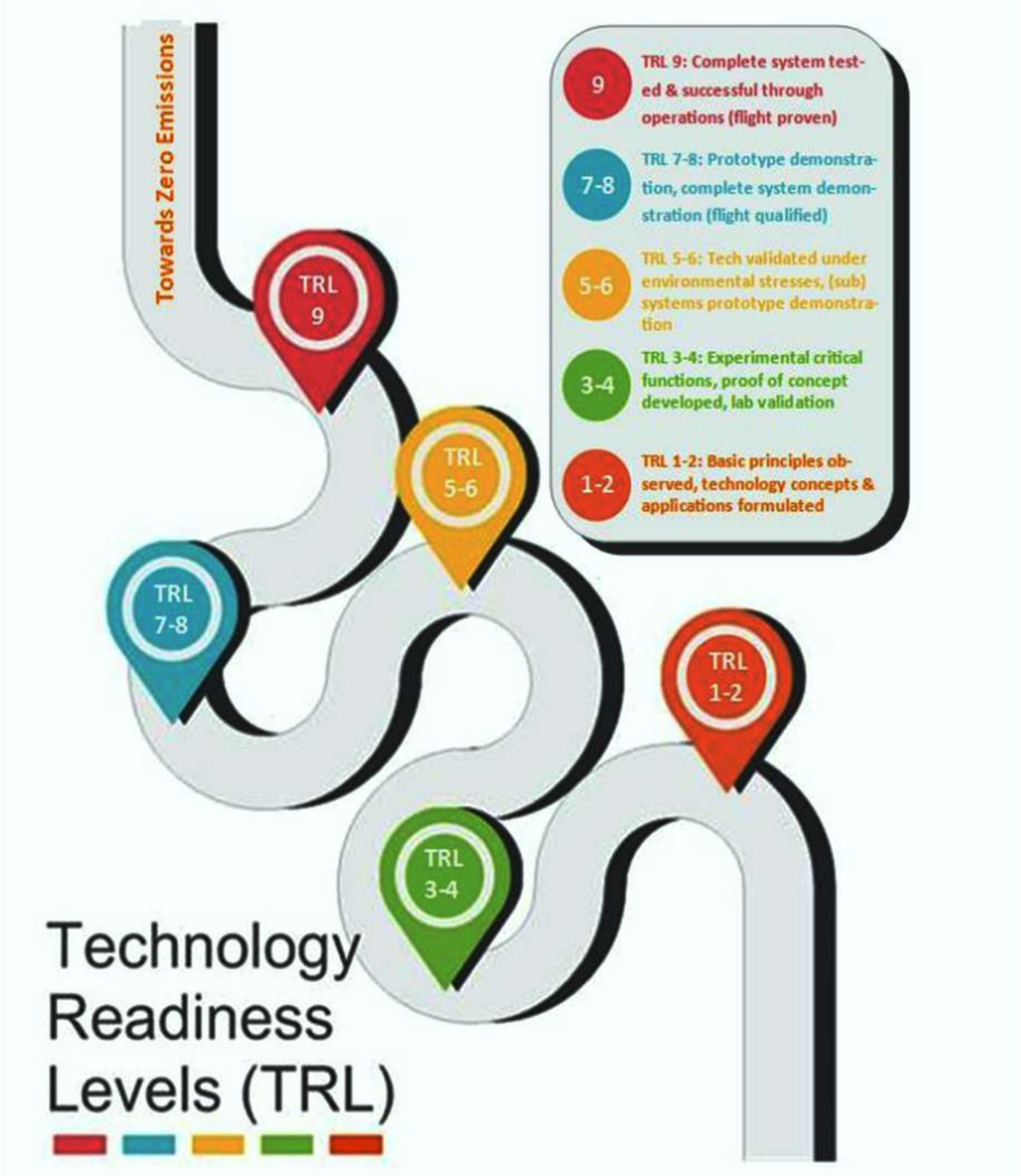


Figure 10.1 Stages of Technology Redness Level

This estimate reflects the fact that the conductive overhead solution has a long-standing history as it is essentially an evolution of overhead rails well as trolley bus technologies, which have been in use for many decades. In light of recent developments, overhead conductive systems are subject to larger and longer demonstrations than alternative ERS concepts for highway use (D Bateman et al., 2018).

10.1 Technical feasibility of inductive ERS

Information gathered on a number of ERS technologies being currently developed and trialled. A total of 17 systems were identified, 11 of that were classed as inductive ERS and these systems are highlighted in Table 10.1.

System	Organisation	Country	Concept / Type	Power & Efficiency	Vehicle Suitability	TRL
OLEV	Dongwon Inc./KAIST	South Korea	Inductive / Dynamic	15-85kW / 71-91%	Buses, LVs, LDVs	9
CWD	Politecnico di Torino / CRF	Italy	Inductive / Dynamic	20kW/ 75-85%	LVs, LDVz	3 to 4
IPV	Seat Emmedi Group	Italy	Inductive / Dynamic	20kW/ 70-80%	LVs, LDVz, Buses, HGVs	3 to 4
PRIMOVE	Bombardier/ scania	Germany/Sweden	Inductive / Dynamic	up to 200kW, 68.8-90%	LVs, LDVs, Buses	5 to 6
HALO	Qualcomm	France/ Germany	Inductive / Dynamic	20kW, 80%	LVs, LDVz	3 to 4
WPT	Oak Ridge National Laboratories / OEM's	USA	Inductive / Dynamic	2.5-20kW, 88-95%	LVs	3 to 4
INTIS	Integrated Infrastructure Solutions	Sweden	Inductive / Dynamic	11-60kW, 88-93%	LVs	3 to 4
Electreon	Electreon Inc	Israel	Inductive / Dynamic	5-20kW, 88-90%	LVs & Buses	5 to 6
Victoria	CIRCE	Spain	Inductive / Dynamic	Up to 50kW, 92%	Buses	7 to 8
WPT	University of California	USA	Inductive / Dynamic	Up to 200kW, 60%	LVs, LDVs, HGVs	2 to 3
Momentum Charger	Momentum Dynamics Corp	USA	Inductive / Dynamic	50-75kW (up to 300kW), 95%	Buses	3 to 4

Table 10.1 TRL for Inductive ERS overview

In this section, the technical feasibility of these inductive systems is discussed in terms of potential advantages as well as disadvantages. The table 10.1 express the details of different ERS ongoing projects in different countries and the list of participants involved in various projects in different countries. The table also explaining which are the concepts of ERS is testing and it is mainly two types called indictive as well as dynamic. the type of vehicles and the power and efficiency of the system are also separately mentioned with TRL ratings for each project.

As a conclusion of the TRL, The KAIST/Dongwon OLEV (from South Korea) and the SIEMENS (from Sweden) systems appear to be the most advanced inductive and conductive ERS technology respectively. Comparatively, University of California WPT (USA) seems to be the least rating in the TRL and it is 2 to 3. The second largest rating of TRL achieved by Victoria CIRCE (Spain) and it is 7 to 8. However, there are a number of technological barriers that need to be overcome for dynamic inductive charging to become feasible. The following issues have been identified as the most immediate issues for inductive ERS manufacturers (D Bateman et al., 2018):

- A number of systems (CWD and IPV) have issues synchronising primary coil segments with the vehicle pick-up. Synchronisation is affected by vehicle speed, lateral alignment, signal switching as well as communications speeds; all of which can impact the power transfer rate as well as overall efficiency.
- There are few inductive systems have low power ratings and it is typically around 20kW, which are only suitable to the light duty vehicles. For powering larger vehicles, power levels, efficiencies and misalignments need to be improved. This is especially relevant with the findings which conclude the only feasible near-term applications of ERS are for metropolitan bus schemes, as well as freight corridors (short long-international haul).
- At current levels of development inductive systems are only capable of delivering power at vehicle speeds of approximately 80-100km/h, which is ideal for trucks which have a maximum highway speed of 90km/h in most states and it is not suitable for the passenger vehicles which would basically travel much faster (up to 120-130km/h).

- Another important issue that needs addressing is the ability of multiple vehicles ton charge on a single segment or coil section. This factor is related to the synchronisation of coils as well as their communication speeds.

One of the main challenges is interoperability, which is the ability of different ERS systems to power electric vehicles regardless of vehicle type. Currently, interoperability does not exist in ERS systems (inductive or conductive) in terms of providing efficient power transfer, from the grid to the ERS, and for multiple vehicle types. In addition, there are no standards or regulations available to provide a clear path for interoperability to occur. IEC 61980177aims to provide standardisation for inductive power transfer for EVs, but guidelines do not exist yet or are still in development (D Bateman et al., 2018).

For ERS interoperability to become functional, it requires communication protocols. In terms of existing standards, the ISO/IEC 15118198 ("Road vehicles -- Vehicle to grid communication interface") standard governs the charging of electric vehicles (ISO/IEC15118198, DIS, 2011), dealing specifically with the communication links between vehicles as well as charging equipment. This standard could be used as a starting point for ERS interoperability.

Other factors that limit efficiencies and power levels between systems include (D Bateman et al., 2018):

- IPR;
- installation depths (similar air gap);
- ERS geometry (coil size, dimensions)
- system architectures;
- Electrical and electromagnetic requirements for conductive as well as inductive ERS respectively

Chapter 11

ERS – BUSINESS PROSPECTIVE

The potential business models for ERS are considered from a road administration perspective. This includes a discussion on the costs associated ERS including the capital costs involved in installing the system and also its on-going operation and maintenance costs. The development of a coherent business model in conjunction with demonstrations of the whole systems including charging technology is needed in order to commercialize ERS. A business model requires identification of the value proposition, customers, revenue source and how it will be obtained, expenses and the actors involved in delivery (Swedish Transport Administration, 2017).

11.1 The electric road system market

The present market and the actors involved can be described in diagrammatic form as shown in the figure below (Swedish Transport Administration, 2017).

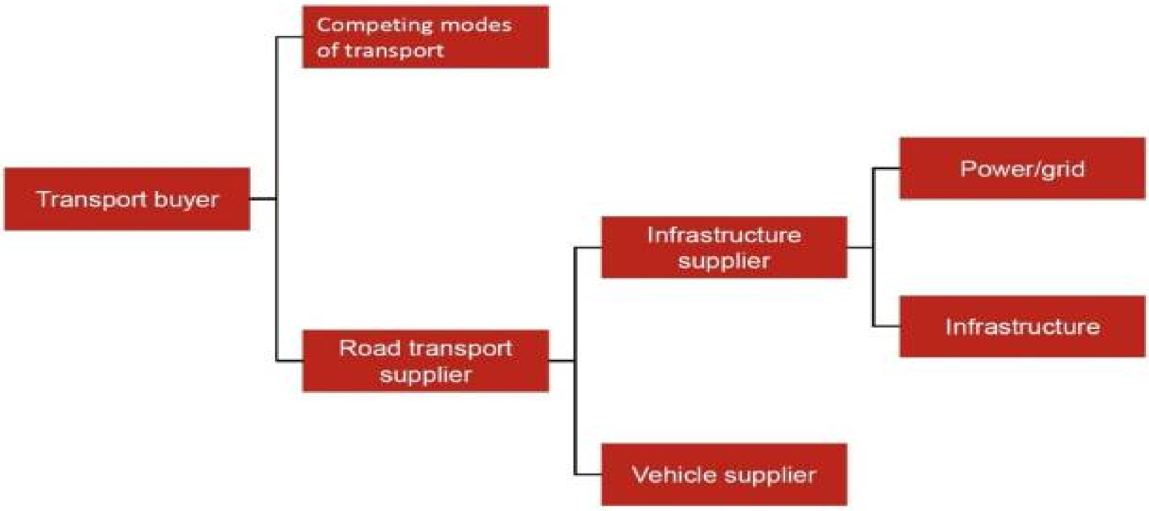


Figure 11.1 Stakeholder network for electric road systems – as a diagram

Figure 11.1 specifies a number of significant functions and their functional or logical links which need to be present in the network building up the electric road system organization. This does not go without saying that the functions will be organized into separate organizational units, but that may well be the case. Whether vertical or horizontal integration can be anticipated is dependent on factors such as how risks and interfaces defined between functions or stakeholders: this is discussed in transaction cost theory, for example. A number of external factors define limits as to how these stakeholder networks operate and influence them continuously. This can be described as shown in Figure 11.2 The transport system – as well as it is largely true of fields such as electric road systems which are made up of actors that are organized in the private sector. These in turn are owned by private sector stakeholders that are funded by customers that voluntarily buy the services offered by the stakeholders, in other words, there is competition. In addition, certain functions are provided by public sector stakeholders. Public stakeholders are owned by the government, regions or municipalities and are largely funded by taxes (sometimes charges) as well as ringfenced with some form of compulsory element, such as a monopoly or compulsory duties.

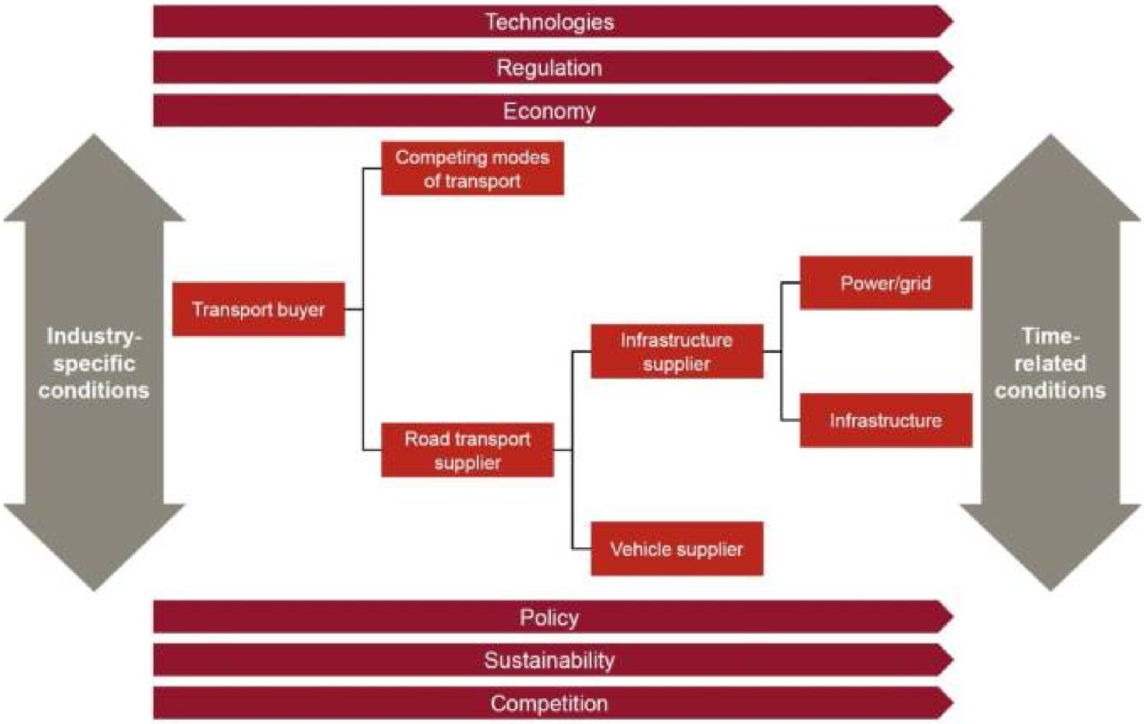


Figure 11.2 Actors network for electric road systems – and limit-defining factors

The balance between functions provided in the public sector as well as those provided in the private sector is changing over time. This is being influenced by technology, the economy and politics, but also by what is known as path dependency. Path dependency means that ingrained patterns for organization tend to have a strong supporting capacity rather than being justified logically or rationally (Swedish Transport Administration, 2017).

There are two different relationship form types in the network described; those characterized by the private – private relationship, and those characterized by the private – public/private relationship. The relationships between private stakeholders involve previously developed roles that do not primarily need to be influenced to any great extent by changing the fuel for transport. In this respect, it may primarily be a matter of facilitating the transition from one technology to another by adapting functionality throughout entire networks as well as reducing risks/costs. An alternative where functions or services should be transferred from market-organized actors to public sector organization does not appear to be a primary option. Against this is the basic view that functions which can be provided in competition and on market-like terms should be provided in this manner in the future as well. However, what should be the subject to more fundamental review is whether the arguments for retaining public provision of infrastructure when electric road system technology is introduced are still sufficient. For historical reasons, the government has chosen different paths for railways and roads in that respect (D. Bateman et al., 2018).

Direct government funding is the basic model for services or functions that it is considered appropriate for the government to own as regards electric road systems. Charges may be considered for utilization of the infrastructure, that in this case these are permitted in accordance with the EU's rules incorporated in Swedish law. It is generally not possible to earmark revenues from such charges for specific purposes according to Swedish law. Therefore, tax instruments may be an alternative to charges. Alternative funding models may be examined for functions/services provided by the government. For example, it may be possible to implement development of electric road system technology on the road network in a public and private partnership (PPP), with the government as the client and project funding from private stakeholders. The government can then compensate the PPP counterparty with accessibility-based charges or transfer the traffic risk to the PPP counterparty by means of a concession, as illustration.

The extent to which there is scope for stakeholders (transport companies and transport buyers) to pay for the costs inherent in investment in electric road system technology is in turn dependent on which fuel taxes the government chooses to apply to the power supplied for road traffic. This is one of the most crucial factors when building up a business model for electric road systems. The various models examined also need to be adapted to the various technologies discussed. A business logic as well as business model that suit one technology will not necessarily suit another business model. The view of how electric road system technology is to be implemented and utilized is a further aspect that has to be analysed. A number of different models are possible and everything from relying on local and regional initiatives to a larger-scale rollout of new technology. Given the major uncertainty as regards the choice of technology, it appears to be reasonable to bring about a number of local facilities during an introductory period where various technologies can be tested. This follows the pattern dating back to the 19th century, when the railways were developed. The government or a private stakeholder will then have to take on the task of refining the use of technology, business arrangements, etc.

For the electric road system market to develop as effectively as possible, experience may also be drawn from other parallel markets and infrastructure areas. In general, the opportunities for rapid market building appear to be favourable if the following aspects are met and taken into account (Swedish Transport Administration, 2017).

- Standards – Voltage levels, AC or DC voltage, the height of overhead lines above the road, and distances between lines. The same open descriptions are needed for solutions in the roadbed. It is imperative to find a balance between the elements of the system that are protected by patents and other rights, and those that are open for various stakeholders to use. It is important not to lock the system into excessively tight patterns, etc., so as to pave the way for competition. This means that special solutions of various kinds in order to meet the demands and wishes of individual suppliers should be avoided.
- Procurability – Open standards, multiple suppliers, competition, etc. provide a foundation to allow solutions to be procured/provided by a number of different stakeholders.
- Clear market communication reduces risks – A clear declaration of intent, open, communicated standards, procurable solutions and clarity from the Swedish Transport Administration and the political system give stakeholders more opportunities to assess risks in the market. This makes development funding cheaper and allows the development of the entire technical field to be accelerated.

The driving force for various parties in the network relating to electric road systems varies, relating to direct and indirect effects of electrification. Electrification will facilitate the development of current working methods, but will also pave the way for completely new business logic, new products and new services. There are differences in business logic between different parties as well as technologies, due mainly to incentives and assignments. Targets for some are instruments for others, problems for some are opportunities for others.

All actors involved in the value chain are needed, but understanding that there are different driving forces is key (Swedish Transport Administration, 2017).

Attention always needs to be paid to the balance between research, development, implementation as well as utilization, along with the ambitions of various parties to patent ideas and earn money along the way. Nowadays, researching, surveying, running demonstrators, developing products and patenting various ERS components using public funding is almost a business concept in itself. This is a reasonable way forwards, but it cannot be allowed to become too great an element in the ongoing development of electric road systems. It is important to take steps towards implementation as soon as possible in order to meet expectations from the political system as well as maintain momentum in the development of the electric road system market (Swedish Transport Administration, 2017).

11.2 Market and its competition

For all ERS concepts it is expected that the main customers will be freight operators using HGVs, although the in-road systems could also be used by LVs on longer journeys providing them with a larger customer base than overhead systems. Passenger cars are likely to charge at home if possible, as this is likely to be cheaper as well as more convenient than public charging facilities. However, on longer journey drivers may choose to top-up on route in which case ERS could be used and some drivers may not have the off-street parking required for installation of charging equipment so would need to use public charging facilities. Intercity buses as well as coaches could also use ERS if static charging at depots and stops are not sufficient for longer journeys. Static charging facilities are therefore a significant competitor technology for LVs, but are currently less relevant to HGVs (D Bateman et al., 2018).

For LVs to take advantage of ERS, they would need to have the appropriate equipment installed, which would add weight and additional cost to vehicles. This may mean that although it technically feasible for them to use ERS it is not practical or economic when there are alternative static systems. Also, the majority of LVs are used mainly for short journeys, whereas HGVs travel long distances. Understanding the potential market for ERS is important as a system designed solely for HGVs may look very different to a system aimed a more mixed user group both technically and in terms of the business model. User behaviour, convenience and cost (initial and operating) will all play a role in determining the potential market and if this will include both freight operators and private cars (D Bateman et al., 2018).

A further consideration is the potential for disruptive technologies around connected and autonomous vehicles, mobility as a service (MaaS) and the sharing economy to radically alter the current business model of privately owned vehicles. Future scenarios could see people pay for mobility as required, which could for example be based on public transport and shared pods in cities, and specific vehicles for longer journeys. A potential future where private vehicle ownership is drastically reduced in favour of shared EVs could drastically reduce the vehicles in urban environments in place of highly utilized electric vehicles that might require some form of dynamic charging. Another aspect which could determine the market for a particular ERS system is interoperability. Currently a variety of technologies have been developed and demonstrated with no interoperability between or within concept types. The various conductive solutions proposed are all inherently non-interoperable, and some (e.g. the Siemens E-road) are limited to limited classes of vehicles. The interoperability considerations for inductive power transfer systems are more advanced. It is recognized that installing multiple non-interoperable systems is not possible, and efforts have been started in standards bodies to standardize the key parameters which will affect interoperability (D Bateman et al., 2018). For example, ISO 19363 standardizes the magnetic field requirements for inductive power transfer, while ISO 15118 addresses the communications interfaces between the vehicle and the infrastructure.

11.3 Market readiness

Technologies which target at different charging modes like static, stationary, dynamic have different technological and investment requirements, which of course affect their technology, manufacturing and market readiness levels. The market readiness mainly on stationary as well as dynamic charging modes since static charging can be considered a mature and market ready technology due to the fact that, there are already many static charging products available to the consumer. The interest in static charging mode was focused on wireless static charging which even though has been widely tested, it hasn’t been mass produced as well as deployed in a large scale yet (Damousis et al., n.d.).

The organizations which are producing wireless charging system are shown in Table 12.1. It was anticipated that, there would be a rather less participation since no incentives were given as well as in addition the requested data may be businesswise sensitive for some of the companies. However, the information gathered from the data combined with the state-of-the-art review allow for an estimation of the current market readiness state of electromobility related systems.

Organization	Product Name	Charging Methord
Conductix-Wapfer	IPT	Static wireless
EVATRAN	Plugless power	Static wireless
HELLA	HALO	Static wireless
WiTricity	utui	Static wireless
Bombardier	Primove	Stationary wireless
Sinautec Automobile Technologies	Capabus	Stationary wireless
Utah State University	WAVE IPT for electric buses	Stationary wireless
INTIS	INTIC	Static/dynamic wireless
KAIST	OLEV	Dynamic wireless
Oak Ridge National Laboratory	ORNL dynamic charging	Dynamic wireless
Elways	Electric road	Dynamic conductive
Siemens	eHighway	Dynamic conductive
Alstom	Alstom APS-ERS	Dynamic conductive

Table 11.1 Market readiness of different organization

As this concept of ERS is still in the developing stage, we cannot draw definitive conclusions for the market readiness of various charging solutions currently under development or testing so the main conclusions derive from the state-of-the-art review. The results of the study are depicted in the Figure12.3 and Figure 12.4. The market readiness can be indirectly estimated as a function of the technology and manufacturing levels for the systems as a whole and critical subsystem. The Manufacturing Readiness Levels (MRLs) meant that communicate

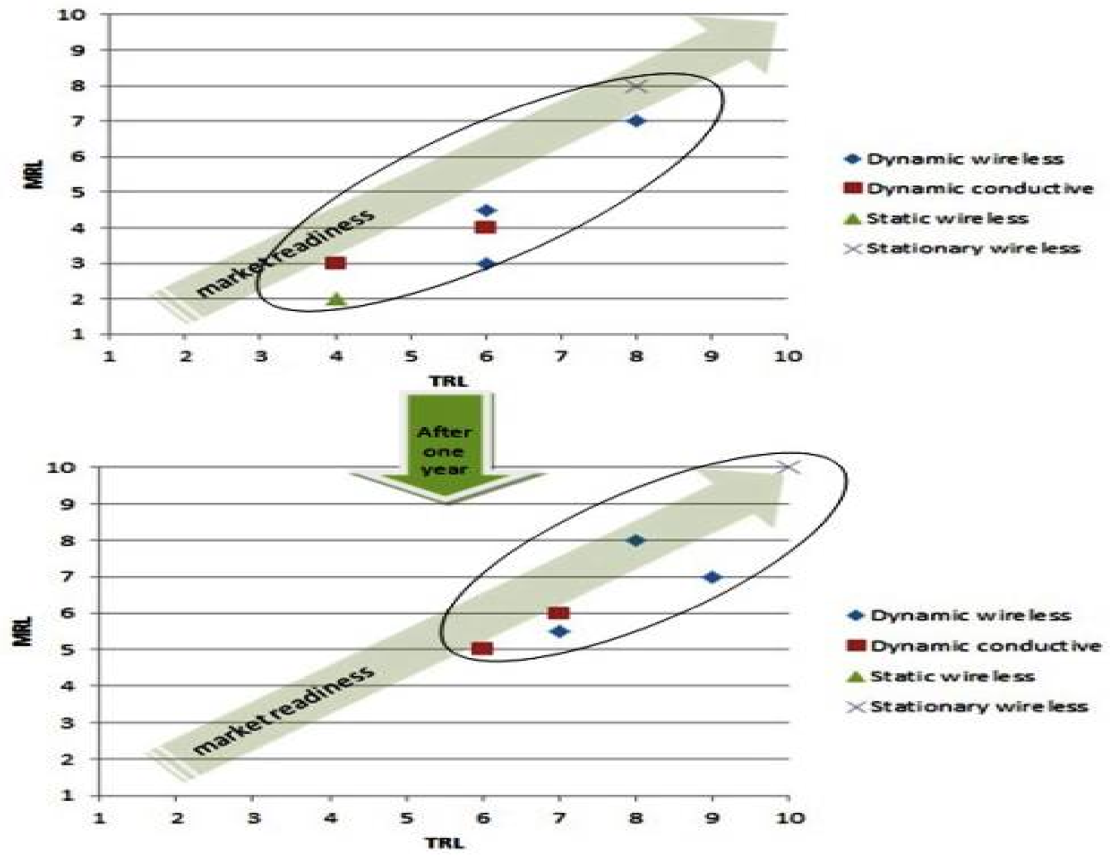


Figure 11.3 Market readiness for complete EV charging system

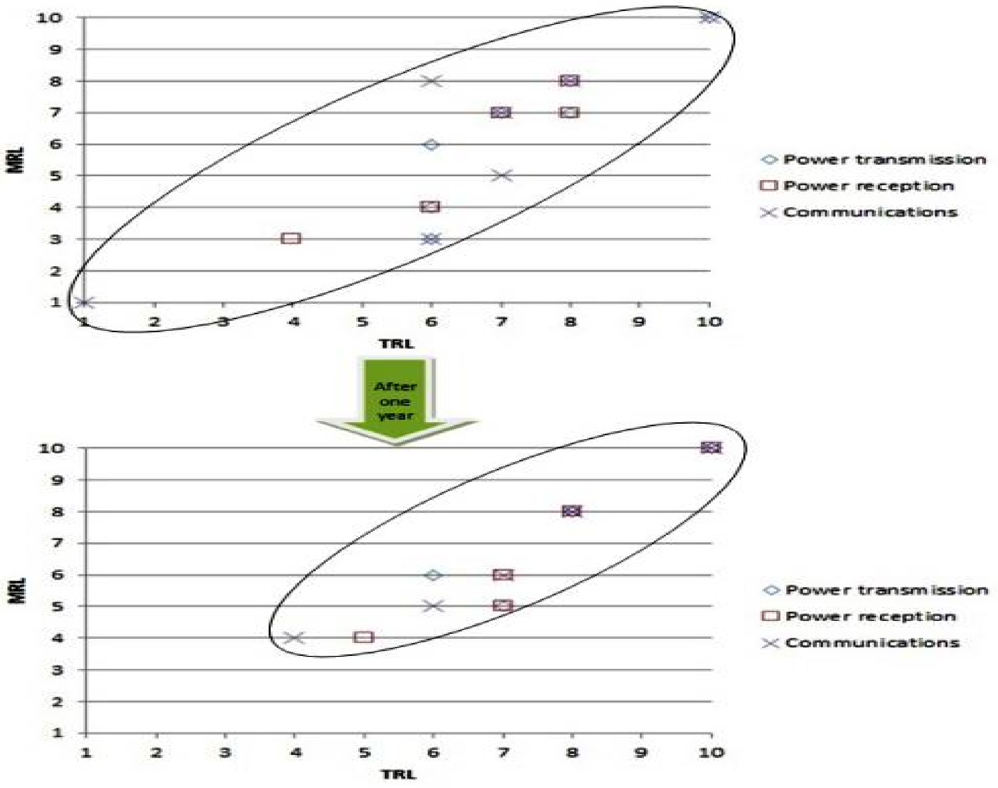


Figure 11.4 TRL and MRL for components of EV charging System

the maturity of a product to be produced. These range from the proof of concept through prototyping to the volume production, deployable globally as well as to appropriate quality levels. However, the actual deployment and commercialization of these products depends heavily on the infrastructure investments that the public as well as private sectors are willing to make (Damousis et al., n.d.).

In the figure 11.3 shows the comparison of Market readiness for the electric vehicle charging system from the initial year and the following year. Stationery charging has the highest redness level in TRL and MRL is 8 out of 8 and 10 out of 10. Dynamic wireless charging has the second highest position in both years which is 9 out of 7 as well as 10 out of 10, this shows the increase in market readiness. Similarly, in figure 11.4 shows the comparison rating of TRL and MRL for components of EV charging System. In the Initial-year, communications have the highest rating of 10 out of 10 but then it changes on the following year. The power receptions also achieve the same position of communications as 10 out of 10. This comparison will give as a clear view that the wireless charging system have a great opening in the upcoming years

11.4 Stakeholder implications

As per the observations from the study, the primary subsystems of ERS will probably be delivered by the firms mainly coming from the railway manufacturing industry and by electric utilities that could produce, distribute, as well as sell electricity. In the following sections, the different actors will be discussed in terms of their role in the conventional road system compared to in the ERS. A comparison could be seen in Figure 11.5

Figure 11.5 Stake holder transition from the conventional road system towards the ERS

For the truck manufacturers, power electrification could be seen as a body builder which building application on the truck chassis. This means that the truck should manage the electrification independent of which power transfer technology that becomes the standard. However, the vehicle will be more integrated with the infrastructure in the new system itself compared to the conventional road system, as it needs to be developed as well connected with the other subsystems. In the beginning of the ERS deployment, ERS could mature in a niche market for different applications like mining and bus system. However, in the long term, ERS could come in to mainstream markets of the truck manufacturers (such as long haulage). The role as well as the value of the core competence for the truck manufacturers, currently being the diesel engine that could change with a switch to the ERS. It would also affect the customer value and service network. So, a shift to ERS would require to the truck manufacturers to acquire new competencies as well as new business models (D. Bateman et al., 2018; “Slide-in Electric Road System, Inductive project report,” 2018).

Petroleum firms will most probably continue to play a significant role with ERS (electrified roads and batteries would not be able to supply the whole road transportation system). The role of these firms could change from being the dominating fuel supplier to the secondary fuel supplier. If vehicles do not need to tank as frequently as today, petroleum companies will lose their sale volumes as well as the number of customers would decrease. This might turn the petroleum firms into new businesses, and the established tank-station networks might complement their current businesses with new applications, such as quick charging and battery swapping (“Slide-in Electric Road System, Inductive project report,” 2018).

One of the main implications for **construction firms** is to ensure safety as well as durance in controlling the construction and properties of the electric roads. As an actor with experience of large projects, construction firms could take the role of integrating the transfer technologies as well as the electric grid into the road construction. Furthermore, the issue of financing new ERS projects might open a new market for public-private partnerships, where construction firms or other like private real estate owners, build and operate electric roads on contracts for the public agencies (“Slide-in Electric Road System, Inductive project report,” 2018).

The main motivations behind the ERS for the **state and agencies** is to reduce environmental impacts, oil imports and increase energy efficiency by switching from fossil to electric fuel.

All other stakeholders have pointed out that the state as well as agencies have a key role as facilitators when it comes to the investing in infrastructure. The loss in oil taxes as well as currency savings from oil imports could require new national as well as international policies. The transition to the ERS may change the financing and owning structure of these roads in order to share the risks and opportunities with private actors that will benefit of new system. The ERS could also be developed as a new export industry in countries which have come far in their development of this technology, such as Sweden, Germany and Korea. Hence, investing in the development of the ERS could result in a new market as well as increased income for states and agencies ("Slide-in Electric Road System, Inductive project report," 2018).

The **users** of the ERS could benefit from higher energy efficiency in the vehicles compared to diesel engine trucks and thus potentially lower fuel costs (although the electricity prices are expected to rise). ERS could also constitute an image as well as brand value to be more environmentally friendly than other alternatives. Despite this, cargo firms might be reluctant to change to ERS vehicles if the infrastructure is undeveloped in the sense that flexibility and uptime is still better in the conventional road system. It is yet unclear that, how much the vehicle prices could be affected due to the ERS equipment and the new powertrain technology. There are also uncertainties concerning about how and to whom the customer should pay for the usage of the ERS ("Slide-in Electric Road System, Inductive project report," 2018).

Road power technology firms could be firms in the railway industry or entrepreneurs. Railway companies have long experience of designing, producing and delivering complete railway systems, including infrastructure as well as intelligence. Trams in urban transportation are one of the main markets for these firms. From past couple of years, the railway companies have introduced different technologies for power transfer from roads to vehicles. These firms are now trying to broaden the better scope for respective technology, to include urban transportation like busses as well as cars, but also trucks and cars on highways. This creates a situation were different technologies are competing with each other ("Slide-in Electric Road System, Inductive project report," 2018). Proponents of the inductive and conductive technologies are pushing for their solution and it is uncertain which solution that will win in the end. Moreover, there are lot off unclear issues concerning how the system will evolve: Will these actors become systems or component providers? Will they sell licenses of their components to other actors or will it be exclusive roads? Will they develop alliances with the partners to deliver a complete ERS or will they provide generic technologies? And how should the revenues within the new value network be shared?

Power companies produce electricity through different energy sources, such as fossil fuels, nuclear and renewables. The traditional way of making money is to sell electric power per kWh to the households and companies. In the electric road system (ERS) scenario, electricity can be the new primary vehicle fuel which opens a new market for the power companies. Designing as well as delivering power station in connection to the power transfer technology as well as the road is a potential business of the power companies ("Slide-in Electric Road System, Inductive project report," 2018). The power grid and stations need to be dimensioned based on the amount of power required for the vehicles at the particular road section. The focusing question for the power companies is: Who will finance the investments in the power subsystem as well as how should the revenues from the vehicle's electricity consumption be captured?

11.4 Revenue sources

Revenue is expected to be generated by charging a fee to customers who choose to charge their vehicles using the technology, most likely this will be through an on-board charging system which calculates the cost based on the amount of electricity consumed (D Bateman et al., 2018) .

A yearly fee or EV vehicle only toll road (e.g. to a port or mine) are also possibilities. The options for fleets and private individuals might be different, and there could be different prices and / or taxes on this basis. Other options for private customers could be to have a private EV allowance as part of a MaaS contract. Different charges could also be applied during peak times or busy routes in order to moderate demand.

In order to be financially possible, the electricity mark-up as well as uptake of the technology need to be sufficient to fund the operation and maintenance of the system as well as payback the initial investment over a reasonable timeframe. It should be noted that the private sector normally expects a higher rate of return on transport infrastructure investments than the public sector e.g. up to 20% to 30%. Another point to consider is the loss of government revenue from fuel tax as VAT on electricity is currently less than diesel in most countries. Whereas the mark-up needs to be high enough to make the ERS economically possible, it also needs to be low enough which users of the system have reduced costs compared to conventional fuels. This includes recouping their investment in vehicle equipment within a reasonable time period. Electric vehicles are more efficient than diesel and electricity is less expensive, so this should be possible. Governments may also wish to subsidize the cost at least initially to encourage take-up (D Bateman et al., 2018).

11.5 Actors and drivers

The commercial delivery of ERS involves complex interactions between several actors, all of which need to benefit from the enterprise. Although reductions in carbon and air pollution are important government policies, these external costs are unlikely to drive customer as well as investor behaviour to the extent economic costs do (D Bateman et al., 2018). For example:

- The customer benefits by obtaining an affordable, convenient, reliable source of power with minimal cost to upgrade their vehicle and little maintenance.
- The government meets its low carbon policy objectives and supports national industry.
- The road administration has a new revenue stream (or at least no additional costs) and meets customer needs and government requirements.
- The electricity supplier sells more electricity and experiences a more balanced electricity demand.

Chapter 12

DISCUSSION AND CONCLUSION

Electric Road Systems (ERS) is a technology area which is currently being tested in several pilot projects in many countries. The technology offers the possibility of using (renewable) electricity in long-distance vehicles transport. This can reduce dependence on fossil fuels, avoid greenhouse gas as well as air pollutant emissions, and increase energy efficiency in the transport sector. There are currently three main concepts for road electrification: overhead lines, conductive rails in a road surface, as well as wireless solutions. In Germany the focus of development and testing is currently on overhead line systems, while in Sweden the whole range of possible solutions is considered. Many other countries like Israel, Japan, USA, South Korea are doing many research and development activities collaborating with universities and industrial companies with the support of governments to have a better version of it. The infrastructure as well as the vehicle configurations can be different variants which can be adapted to the respective conditions as well as can take further technological advances (e.g. in battery development) into account. The three conceivable energy supply systems are all still in the development phase, and the various solutions have different levels of maturity. Robust assessments of system specific strengths and weaknesses, as well as credible validations of infrastructure costs estimates need further studies and advanced demonstrations in operational environments. However, when it comes to the consideration of the efficiency of energy transfer compared with cable-connected charging, it is fact that the efficiency of Qualcomm Halo WEVC technology is comparable to the conductive charging systems at same power ratings. The industry target for a commercial WEVC system with 90% efficiency and above. A very high-quality conductive charging system could have efficiency figures in the mid-nineties due to losses in isolating and control circuitry, components, connectors as well as cabling. However, some of the conductive charging systems are reported to have losses around 15% or more and if It say accurately, the conductive charging will usually be 1 or 2% more efficient than wireless. As the power increases say from 3.3kW to 6.6kW as well as up to 20kW the charging efficiency can improve since the standing losses are the same for all power levels. For example, the 7kW system on the Rolls Royce Phantom 102EX Experimental Electric Vehicle was shown to operate at over 90% (Europæiske Miljøagentur, 2016).

while discussing about the wireless charging it is also considered that, how quickly can wireless technology charge an average EV battery. Basically, the charging times between wireless as well as plug-in charging are the same as it depends on the power rating of the charging system. To illustrate, the Qualcomm Halo WEVC systems at 3.3kW as well as 7kW are suitable for home charging, 7kW is ideal for public charging as well as 20kW for fast charging. If a 27kW battery was depleted to 6kW then it would need 21kW of charge. The charging time is then a simple case of dividing the energy required by the amount of power transferred into the system. So, at 3.3kW the charging time would be around six and a half hours. The charge time would reduce to a little over three hours if the power level was 6.6kW (Europæiske Miljøagentur, 2016).

Why do we need wireless charging! for this question some of the investigators say that, the big OEMs [original equipment manufacturers] are not investing so much anymore in complete battery electric vehicles but more into the combination of electric with combustion engines. As per the updates Toyota has reported that, with their plug-in hybrids people don’t use the cables to charge their vehicle batteries because they have the combustion engine on board as well as they would rather go to the petrol station. So now everybody is going for automatic charging.

In addition to ERS, other technology options are available in the principle for decarbonizing long-distance vehicles, even if most of them have not yet reached full market maturity. Battery electric as well as fuel cell vehicles are discussed as alternative drive systems. Battery electric vehicles in particular are attracting increasing attention as a result of the advances in energy storage technology. A further option is a continued use of the combustion engine in combination with renewable fuels such as biomass-based fuels as well as electro fuels. In a comparison of technologies, the direct use of electricity by means of batteries or ERS is characterised by the greatest energy efficiency and likely the lowest overall costs. Fuel cell vehicles, on the other hand, have significantly lower energy efficiency as well as higher overall costs. The use of renewable fuels in internal combustion engine vehicles is characterised by the highest total energy requirement.

All alternative drive systems require the development of additional energy supply infrastructure and they are also associated with higher vehicle costs, at least during the introductory phase. As this concept of ERS is still in the developing stage, we cannot draw definitive discussion for the market readiness of various charging solutions currently under development or testing so the main conclusions derive from the state-of-the-art review. However, when the TRL and MRL are in consideration, the following are valuable in both technological as well as business perspective.

TRL

- Innovative
- Testable
- controllable
- Compatible to industrial and social standards
- implementable
- assimilative

MRL

- Unsatisfied needs identified
- Identification of the potential business opportunities
- System analysis and general environment analysed
- Market research
- Target defined
- Industry analysis
- Competitors analysis and positioning
- Value proposition defined
- Product/service defined
- Business model defined coherently

In addition, if both TRL and MRL comparing each other for the future development the risk factors involved in it are also considered. The following table 12.1 shows the general view of the risk involved in the rating of TRL and MRL.

Column1	TRL < 5	TRL > 5
MRL > 5	Market available, no technology => MARKET RISK	Market & Technology coherently mature
MRL < 5	Market & Technology in coherence, but not mature	Technology available, No Market TECHNOLOGY RISK

Table 12.1 Risk involved in managing TRL and MRL

For the electric road system market to develop as effectively as possible, experience may also be drawn from other parallel markets as well as infrastructure areas. In general, the opportunities for rapid market building appear to be favourable if the following aspects are met and taken into account (Swedish Transport Administration, 2017).

- Standards – Voltage levels, AC or DC voltage, the height of overhead lines above the road, and distances between lines. The same open descriptions are needed for solutions in the roadbed. It is imperative to find a balance between the elements of the system that are protected by patents and other rights, and those that are open for various stakeholders to use. It is important not to lock the system into excessively tight patterns, etc., so as to pave the way for competition. This means that special solutions of various kinds in order to meet the demands and wishes of individual suppliers should be avoided.
- Procurability – Open standards, multiple suppliers, competition, etc. provide a foundation to allow solutions to be procured/provided by a number of different stakeholders.
- Clear market communication reduces risks – A clear declaration of intent, open, communicated standards, procurable solutions and clarity from the Swedish Transport Administration and the political system give stakeholders more opportunities to assess risks in the market. This makes development funding cheaper and allows the development of the entire technical field to be accelerated.

The driving force for various parties in the network relating to electric road systems varies, relating to direct and indirect effects of electrification. Electrification will facilitate the development of current working methods, but will also pave the way for completely new business logic, new products and new services. There are differences in business logic between different parties as well as technologies, due mainly to incentives and assignments. Targets for some are instruments for others, problems for some are opportunities for others. All actors involved in the value chain are needed, but understanding that there are different driving forces is key. The challenges of scaling up, Elect Road is optimistic about the growing synergies between its vehicles as well as electric grids that are transitioning to renewable energy sources like solar and wind, instead of fossil fuels. So, many of the leading companies and developing countries are more focusing in the wireless charging technologies and its future markets (D. Bateman et al., 2018).

12.1 Advantages, disadvantages and challenges

Wireless inductive charging could help popularise electric vehicles (EVs) by making it quicker as well as easier to top up the battery. If the technology could be installed into roads, it might even be possible to charge EVs as they are driving by the process of dynamic charging. The system creates a localised electromagnetic field around a charging pad and it is activated when an electric vehicle with a corresponding pad is positioned above it. The field induces a current in the receiving pad, supplying current which can recharge the battery. It also means that the vehicles can make do with far smaller batteries (they still need them for acceleration), which can save a lot of weight as well as expense. The major advantages of wireless charging are that it allows for significantly smaller batteries or the ability to travel longer distances with a larger battery and Both are convenient, says Burak Ozpineci, who works on wireless technologies at Oak Ridge National Laboratory in Tennessee. In addition, the advantages of Electric Road’s technology may become less important as electric vehicle batteries get cheaper, lighter and more efficient. Breakthroughs in engineering as well as chemistry have made batteries much more cost-efficient over the past 15 years, says Dustin Grace, director of battery engineering at Proterra, an electric bus company. The placing of inductive charging hardware on the road will be safer, prettier, as well as more versatile than using live overhead lines to power electric vehicles.

The ERS technologies reviewed (including static charging and plug-in charging solutions), the plug-in charging systems were identified as the system to present the lowest level of risk. Comparatively, the inductive and conductive overhead ERS presented similar levels of risk (very low-medium), with the conductive rail ERS showing higher levels of risk overall. Once risks are considered to be tolerable, the system should be tested as well as trialled both off and on road to validate identified risks and tolerability of risk decisions. Future maintenance of roads containing ERS is highly dependent on the type of construction that required for each system and the design life of the in-road components of the ERS. Conductive overhead ERS should have no impact on road condition and expected maintenance operations. For conductive rail as well as inductive ERS, collaborative studies between technology manufacturers and road authorities should demonstrate if the ERS is durable enough to withstand the conditions experienced on heavily trafficked motorways and will require limited maintenance during its service life. The expected ERS maintenance varies depending on system type; ERS technologies reviewed in this report indicate that for some types maintenance may be required every 10-30 years while others are expected to be maintenance free over their lifetime.

From the understanding, the cost of dynamic WPT is very high but the power transfer density is particularly problematic for this dynamic WPT, this system requires very high-power capability for transfer required energy to the vehicle while its very short time passing over a charging coil. Due to this the dynamic inductive WPT is yet to become communally feasible, although a smaller number of systems have been experimented. Capacitive WPT system does not use ferrites, they can be operated at higher frequencies, allowing them to small and less expensive. Capacitive WPT system then implements dynamic EV charging systems. This is using because the distance between the road and electric plates is very small, effective power transfer will occur only at very high frequencies, this will reflect while the designing the vehicle charging system it’s a challenging one. Static charging solutions and electric battery technology seems to be complimentary to ERS development and implementation. Advancements in these areas should see an increased uptake of EVs which reduces concerns for road users and promotes the use of EVs. Uptake of EVs using these battery solutions may only be suitable for light vehicles and commercial buses rather than HGVs due to battery size and charging time constraints. However, the greater power transfer efficiencies associated with conductive charging solutions may reduce the potential implementation of ERS particularly for buses and light vehicles. Biofuels are only an intermediate step in decarbonisation as they are not zero carbon. The lack of refuelling infrastructure also means biofuels and alternative fuel options such as hydrogen fuel cells may struggle to generate growth in their respective areas. Results from the CBA showed that emission savings (CO2, NO2 and PM) were similar for conductive rail and inductive ERS as these systems were analysed for both light vehicles and HGVs. Only HGVs were included in the analysis for conductive overhead systems, so the reductions were not as great. Vehicle emissions in the model were calculated using UK-specific emission factors. These are lower for new vehicles. Equivalent emission factors vary significantly with the age and composition of vehicle fleet, as well as other factors such as maintenance and driving style.

12.2 Conclusion

To put it in a nut shell, Biofuels are only an intermediate step in decarbonisation as they are not zero carbon. The lack of refuelling infrastructure also means biofuels and alternative fuel options such as hydrogen fuel cells may struggle to generate growth in their respective areas.

The static charging solutions and electric battery technology are, can be a greater complimentary factor for ERS development as well as implementation. Advancements in these areas should see an increased uptake of EVs which reduces concerns for road users as well as promotes the use of EVs, thereby increasing support for dynamic ERS solutions where circumstances allow. Uptake of EVs using these battery solutions may only be suitable for light vehicles and commercial buses rather than HGVs due to battery size and charging time constraints. However, the greater power transfer efficiencies associated with conductive static charging solutions may reduce the potential implementation of ERS particularly for buses and light vehicles. The cost of the dynamic ERS system is very high but the power transfer density is particularly problematic for dynamic WPT, this system requires very high-power capability for transfer required energy to the vehicle while its very short time passing over a charging coil. Due to this the dynamic WPT is yet to become commonly feasible, although a smaller number of systems have been experimented. Once this technology can be a great success, then it will be the most feasible and effective method for electrification of vehicles.

In this study, from the analysis of technology readiness and market readiness were carried out and showed a wide range varying from TRL 2-9. The majority of the Wireless charging ERS systems (50%) scored between TRL 3 and 4, whilst only very few systems had a TRL greater than 6. The majority of the conductive ERS systems (60%) scored between TRL 4 and 5, whilst the remaining few systems had a TRL between 6 and 8. The KAIST/Dongwon OLEV (from South Korea) and the SIEMENS (from Sweden) systems appear to be the most advanced inductive and conductive ERS technology respectively and those closest to market readiness. A conclusion that we can reach from the results concerns the trend towards market readiness of dynamic conductive as well as wireless charging solutions which are currently in R&D phase and testing. There are optimistic estimations about the near future market readiness state of dynamic charging products. However, the actual deployment and commercialization of these products depends heavily on the infrastructure investments that the public as well as private sectors are willing to make. The majority of the remaining ERS technologies are still at demonstrator stage and require or are in the process of undertaking on-road trials to determine their technical feasibility. Power outputs were generally greater for conductive ERS which showed greater capability for charging HGVs, whilst inductive ERS appears to be more suited to powering lighter vehicles as well as buses, with the exception of the Bombardier system which is currently conducting testing with HGVs. The majority of the conductive ERS systems were capable of achieving efficiencies greater than 90%, whilst the inductive ERS efficiency levels had greater variation between 70-95%. The main challenge for inductive ERS functionality is to improve power transfer efficiency as well as maintaining it for different vehicle types. Currently, interoperability is practically non-existent for all ERS systems.

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Appendix

I. Interview Questions

Interview Questions	Respondent
Do you feel that there is a need to standardize the electric road system?	A
What is the value of the ERS in the technologically advanced era?	A
What risks are involved with investment in the implementation of dynamic ERS?	B
What other factors can affect the development and implementation of ERS on a wide scale?	B
What perspective is taken with the business analysis you are conducting on ERS?	B
Is the technology competitive?	A
Is the system safe to use?	A
What do you think about the future market success for ERS?	B
How quickly can wireless technology charge an average EV battery?	A
In your perspective how effective the value preposition will be for the customer segment in this particular business model?	B
What are the possible channels to reach the customers and to utilize the potential effect to create revenue generation for all electric vehicle companies?	B
How the Actors influence in the development of ERS system?	B
How effective the Technology Readiness Level and estimated time to deployment?	A
What are the present challenges and barriers for further development?	A

II. Information gathered from Other sources

- https://youtu.be/YIu_rsF3uNU
- https://youtu.be/nq6e-0SRlz0
- https://youtu.be/VZNHZnyxCm8
- https://youtu.be/BtaAp_wTr7E
- https://youtu.be/RQmmsPvczVo
- https://youtu.be/0C4175UuuhA
- https://youtu.be/ZFOha8ZWViw
- https://youtu.be/YjAlsxUOGzQ
- https://youtu.be/E1jHWqyErHA
- https://youtu.be/R9zvbKdrIqA
- https://youtu.be/mu-eaQFTdgQ
- https://youtu.be/J5Gd5YQwOys
- https://youtu.be/jXBph31lxtU
- https://youtu.be/sYPzB1g5_5E
- https://youtu.be/r379RWU_EA0
- https://youtu.be/ljSjW6sflzA
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- https://www.ri.se/en/our-stories/finding-sustainable-future-electric-roads
- https://www.scania.com/group/en/worlds-first-electric-road-opens-in-sweden/
- https://www.express.co.uk/life-style/cars/990524/Wireless-charging-roads-electric-cars-UK
- https://www.theverge.com/2019/3/21/18276541/norway-oslo-wireless-charging-electric-taxis-car-zero-emissions-induction
- https://futurism.com/ev-charging-roads-sweden

- https://www.cnet.com/roadshow/news/charge-your-car-by-just-driving-it/
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- https://www.phoneworld.com.pk/qualcomms-inductive-charging-lets-you-charge-cars-while-driving/

Padma kumar Parameswaran Thampi, Graduated Master's Degree in Manufacturing Engineering from Annamalai University, India 2010. Currently pursuing a Master's Degree in Industrial management and Innovation from Halmstad University, Sweden

Thomas Paul Thodukulam Poulose, Graduated Batchelor's Degree in Aeronautical Engineering from Anna University Chennai, India 2018. Currently pursuing a Master's Degree in Industrial management and Innovation from Halmstad University, Sweden.

HALMSTAD
UNIVERSITY

PO Box 823, SE-301 18 Halmstad
Phone: +35 46 16 71 00
E-mail: registrator@hh.se
www.hh.se